State of California
THE RESOURCES AGENCY
Department of Water Resources

BULLETIN No. 136

NORTH COASTAL AREA INVESTIGATION

Appendix A
WATERSHED MANAGEMENT IN THE EEL RIVER BASIN

SEPTEMBER 1966

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

Division of Beaches and Parks Photograp

1. South Fork Eel River near Weott. Mouth of Bull Creek and Rockefeller Grove in the foreground, Humboldt Redwoods State Park.

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FOREWORD

This report deals with the current and historical watershed management problems of the Eel River Basin, the responsibilities of state and federal agencies with respect to watershed management, and the watershed management needs in the Eel River area.

This appendix is one of the supporting documents for the report on the North Coastal Area Investigation, which consists of the main report, Bulletin No. 136, and several separately bound appendixes and office reports. The appendixes are "A, Watershed Management in the Eel River Basin"; "B, Recreation"; "C, Fish and Wildlife"; and "E, Engineering Geology". Office reports have been published in limited quantity on hydrology, design and cost estimates, and alternative plans for development. The economics and land and water use data utilized in the investigation have been published in Bulletin No. 94-8, "Land and Water Use in the Eel River Hydrographic Unit", and in Bulletin No. 142-1, "Water Resources and Future Water Requirements in the North Coastal Hydrographic Area".

These appendixes, office reports, and associated bulletins contain the data upon which the conclusions and recommendations in Bulletin No. 136 were based. The emphasis in the main bulletin is on concepts, conclusions, and recommendations rather than on reporting of data.

This appendix, published in preliminary form in June 1964 and now updated to include public hearing comments, was prepared in response to Senate Concurrent Resolution No. 47 of the 1961 State Legislature. The resolution requested that a comprehensive survey of the Eel River watershed be made in relationship to the water, flood control, and watershed management needs of the eight member counties of the Eel River Flood Control and Water Conservation Association. The first two items -- water and flood control -- are reported upon in considerable detail in Bulletin No. 136 and its supporting documents. Watershed management needs are reported herein.

Valuable assistance, advice, and data in this study were contributed by agencies of the state and federal governments and by private organizations and individuals. This eager cooperation is gratefully acknowledged, for without its benefit, the execution of this work would have been much more difficult. Special mention is made of the helpful cooperation of the following organizations and individuals: California Department of Fish and Game; California Division of Beaches and Parks; California Division of Forestry; California Division of Soil Conservation; University of California; Humboldt State College; U. S. Forest Service, Mendocino and Six Rivers National Forests; U. S. Soil Conservation Service; U. S. Geological Survey; Pacific Lumber Company, Scotia; The Nature Conservancy; the California Forest Protective Association; and Mr. Heath Angelo, Branscomb.

William E. Warne

William E. Warne, Director
Department of Water Resources
The Resources Agency
State of California
June 29, 1966

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PUBLIC HEARINGS
on
Preliminary Edition
of
Bulletin No. 136, Appendix A

Pursuant to the Water Code and Department of Water Resources policy, the Department and the California Water Commission held joint public hearings on Bulletin No. 136 and Appendix A. These meetings were held in Willits, Willows, Weaverville, and Eureka on February 3, 4, 9, and 10, 1965, respectively. An additional hearing was held in Weaverville on March 15, 1965. Only comments offered on Appendix A are discussed here.

At Willits, Willows, and Weaverville, representatives of the U. S. Department of Agriculture, Soil Conservation Service, outlined plans for a River Basin Study of the Eel River watershed under provisions of Section 6 of Public Law 566, to be carried out in cooperation with the U. S. Forest Service and the Economic Research Service. This study will survey land erosion problems and causes, stream sediment loads and turbidity, land conservation needs and possible USDA-type projects for the solution of problems in land and water resource management.

In Willits, Mr. Lloyd Bernhardt, representing the U. S. Forest Service, discussed the role of his agency in meeting the watershed management needs of the Eel River basin. Mr. Bernhardt urged the use of small headwater dams for debris control and meeting local water needs.

In Willows, Mr. Lewis Reese of the California Division of Forestry commented on the relationships between reservoirs, recreation, fires, fire prevention, and watershed protection. He urged the judicious use of soil-vegetation maps in engineering studies.

In Eureka Dr. Peter E. Black suggested that, "adverse effects resulting from land use definitely played a role in the recent floods and their resultant damage, and research is needed to ascertain the magnitude of this effect and to insure protection for future works . . ." Dr. Black also challenged the concept outlined in the appendix that on larger watersheds, effects of land use became less important, and stressed the havoc that even a small disturbance can create in upsetting the established regimen of a stream.

Only minor rewriting was necessary to prepare this bulletin for final publication.

State of California
The Resources Agency
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ABSTRACT

Watershed management, as defined for the purposes of this Eel River study, is the art and science of managing the land, vegetation, and water resources of a drainage basin for the control of the quality, quantity, and timing of water, and for the purposes of enhancing and preserving human welfare.

The broad objective of watershed management is to manage the land and water resources for hydrologic ends desirable to human welfare. The goals of watershed management are attained through three routes: (1) the rehabilitation of lands damaged by inappropriate land use and inadequate former management, (2) the maintenance of a present level of management at acceptable standards, and (3) the improvement of currently well-managed or natural lands for even greater hydrologic benefit of man. A fourth objective of watershed management, analysis of the present situation, can also be mentioned. This study of the Eel River Basin falls under this fourth objective.

In the Eel River Basin, the specific objectives of watershed management should be: (1) to control the production sediment, (2) to make maximum hydrologic use of the soil mantle and vegetative cover, and (3) to yield the maximum harvest of vegetation, consistent with items 1 and 2 above, in a manner compatible with man's desires and economic needs.

A basic need in watershed management, as pointed out in this report, is for an interested public that is well informed as to the nature and occurrence of erosion and sedimentation and aware of watershed management techniques and effects. To further this end, educational activities directed toward the public, in the fields of resource conservation and use, should be supported and encouraged by all parties concerned.

A specific watershed management need, of particular importance in the Eel River watershed, is for detailed study of sedimentation problems as related to water development.

This watershed management analysis of a specific drainage basin, made concurrently with an overall water conservation development plan, is a pioneering step in California. So far as is known, this approach has never before been attempted in past state water project formulation.

CHAPTER I. INTRODUCTION

The present and anticipated future dynamic growth of the State of California has placed a tremendous demand upon our water resources and has presented those responsible for the development of these resources with an unprecedented challenge.

California is blessed with sufficient natural water supplies to meet present and all probable future needs, provided these supplies are prudently controlled, conserved, and distributed. In recognition of the importance of water to the maintenance of an expanding economy and to the health and welfare of the citizenry, provisions are being made to meet this unprecedented challenge of developing the State's water resources. Federal, state, and local levels of government are proceeding vigorously toward fulfillment of this goal. In the North Coastal area of California is found a large part of the State's remaining surplus waters, sufficient in quantity and quality to meet its needs.

This chapter will briefly describe the North Coastal Area Investigation and the scope of this appendix. The geographic area covered by the investigation includes all of the area draining to the coast north of and including the Russian River Basin and related areas tributary to the possible large storage reservoirs on the west side of the Sacramento Valley. The major watersheds involved are the Klamath, Trinity, Mad, Eel, and Russian River Basins.

North Coastal Area Investigation

A primary mission of the Department of Water Resources is the implementation of the State Water Resources Development System. As defined

in the California Water Resources Development Bond Act of 1959, popularly known as the Burns-Porter Act, this system includes the Central Valley Project, the State Water Facilities under construction, and the additional facilities that may be authorized by the Legislature or the Department of Water Resources to augment water supplies in the Delta and to meet local needs.

Need

In recognition of the necessity to specifically define major multipurpose projects to follow the Feather River Project (subsequently designated State Water Facilities by the Burns-Porter Act), and the Central Valley Project, and to establish their logical sequence of development, the department initiated the North Coastal Area Investigation in July 1958. The initial reconnaissance phase of the continuing investigation was completed with the publication of Bulletin No. 136 in September 1964. As a result of this study, the Upper Eel River Development was selected as the initial North Coastal unit of the State Water Facilities. The Water Resources Development Bond Act, passed by the Legislature in 1959, and approved by the voters in 1960, provided added official recognition of the necessity for developing additional water supplies; and within certain limitations, the act provides for the financing of succeeding additions to the State Water Resources Development System.

The objective of the North Coastal Area Investigation is to formulate plans for the optimum development of the water resources of the region, considering all potential uses, including anticipated local and export water supply needs; preservation and enhancement of fish and wildlife resources; development of hydroelectric power and water-associated recreation potential; and protection against floods.

Scope

The first phase of the North Coastal Area Investigation was conducted at a reconnaissance level of intensity. The scope of the investigation, as extended to include related studies of areas in the west side of the Sacramento Valley, is comprehensive with regard to the multipurpose uses of the prospective export facilities. These uses include provisions, where indicated, for distribution of water supplies to local areas, control of floods by reservoirs, generation of hydroelectric power, fisheries preservation and enhancement, and development of recreation potential.

The program for the investigation covered all aspects of development, control, and conveyance of water. Studies ranged from cursory examination of alternatives to semi-detailed analysis of selected project units and features. The investigation included field work and office studies within the following categories: watershed management, hydrology and meteorology, geology, surveys and topographic mapping, land and water use, water quality, economics, property appraisal, and fisheries and recreation evaluation. Operation studies to determine conservation yield, hydroelectric power capability, flood control potential, and other factors for prospective multipurpose reservoirs and export systems were conducted by both conventional and electronic machine computing methods. The intensity of design studies and cost estimates ranged from reconnaissance to reasonably detailed analysis. Based on these studies, the more favorable major projects were selected for more intensive feasibility-level studies.

Selected Projects

The long-range development plans within the North Coastal and West Side Sacramento Valley areas which are recommended in Bulletin No. 136 for

more intensive studies leading toward authorization and future construction are listed below in the order of recommended development at this time.

Upper Eel River Development

Trinity River Developments

Trinity Diversion Project

South Fork Trinity Project

Mad-Van Duzen Project

Greater Berryessa Project

Lower Eel River Development

Klamath River Projects

The Upper Eel River Development, the most favorable project recommended in Bulletin No. 136, was authorized in March 1964 as an additional facility of the State Water Resources Development System. Possible plans of the Upper Eel River Development are shown on Plate No. 6 at the end of this appendix and are described in some detail in Chapter II. It will be noted that two alternative diversion routes for the Upper Eel River surplus waters are shown: the Glenn Reservoir and Clear Lake diversion routes. Final route selection will be made in June 1967.

Future Study Program

With the publication of Bulletin No. 136, the reconnaissance investigation in the North Coastal area was completed. Since July 1964, departmental efforts in this area have been confined primarily to two interrelated but distinct studies. These studies are:

1. An advance planning investigation of the Upper Eel River Development as selected for early state construction, and portions of that development identified for joint state-federal development.

The objective of the advance planning investigation is the final formulation of a project or projects which will meet the requirements for additional facilities of the State Water Resources Development System.

2. The second study is a continuation of the area-wide investigation of the remainder of the North Coastal area. This investigation is at an intermediate level of intensity directed toward the more detailed identification of future projects within the Trinity, Mad, Van Duzen, Lower Eel, and Klamath River Basins. The objective of this study is to further define the specific features of the second and later-staged developments recommended in Bulletin No. 136, in anticipation of future feasibility-level studies.

Scope of Appendix A - Watershed Management in the Eel River Basin

This study of the watershed management needs within the Eel River Basin has been prepared in compliance with the request of Senate Concurrent Resolution No. 47 of the 1961 Legislature of the State of California[1/]. The resolution reads in part as follows:

> "... the State Department of Water Resources is requested to proceed as quickly as is feasible to make a comprehensive survey of the Eel River Watershed area in relationship to the water, flood control, and watershed management needs of the eight counties which are members of the Eel River Flood Control and Water Conservation Association ..."

Since the water and flood control aspects mentioned in this resolution were already being studied in other phases of the department's North

1/ Calif. Stats. 1961, Res. Ch. 210, p. 5003.

Coastal Area Investigations, the particular study as reported herein was initiated to satisfy the watershed management provisions of the resolution. In matching the resolution requests with the department's available manpower and time resources, it was necessary to restrict the study program in two respects. These were to make the study extensive rather than comprehensive in nature and to limit it to the Eel River Basin proper, rather than the suggested eight county area. A watershed management analysis of a specific drainage basin, concurrent with an overall water conservation development plan is a pioneering step in California. So far as is known, this approach has never before been attempted in past state water project formulation. Therefore, a good deal of time was spent in consideration of the meaning and scope of "watershed management," in prudent anticipation of future departmental activities in this field.

What is watershed management? Inquiry into this simple question showed that extensive meanings are applied to the term, the exact import depending almost entirely upon the "authority" consulted. Variations in tenor include regional and river basin planning, water management, coordinated land use planning, comprehensive political and human management, multiple use management, soil and water conservation, coordination of land and water uses, and soil erosion control. There is no one resource which is of primary concern to all variations. Three resources, however, appear to be the central ingredients of the watershed management concept. These are the soil, the water, and the vegetation, as they relate to the people's needs and desires.

As the Department of Water Resources is concerned with the management of the water and water-related resource, some phases of watershed management are of prime concern to it. Similarly, the department can concern itself

only with those features of watershed management which directly or indirectly affect the water and water-related resource. With these restrictions and limitations in mind, the following definition of watershed management has been proposed for this Eel River study:

> "The art and science of managing the land, vegetation, and water resources of a drainage basin for the control of the quality, quantity, and timing of water, and for the purposes of enhancing and preserving human welfare."

This definition is presented with the full knowledge that individual workers can find cause to take exception to it. The engineering aspects of watershed management are and have been under study by various agencies, including the Department of Water Resources, and are academically classed as water management. The remaining discipline, i.e., combining and stressing the soil and vegetative influence upon water, is termed watershed management by the land management sciences. This report has been written with this latter concept in mind.

The broad objective of watershed management then is to manage the land and water resources for hydrologic ends desirable to human welfare. The land surface provides the means of gathering water to a point through drainage features. That which happens to the land affects the quantity of water delivered, its timing, and its condition upon arrival. Thus, the goals of watershed management are attained through three routes: first, the rehabilitation of lands damaged by inappropriate land use and inadequate former management; second, the maintenance of a present level of management at acceptable standards; and third, the improvement of currently well-managed or natural lands for even greater hydrologic benefit of man. These three routes may be considered as first aid, hygiene, and improvement. The

first (first aid) is a danger sign, the second (hygiene) is acceptable, and the third (improvement) is a sign of intensive management, a condition not commonly found in the United States. A fourth objective of watershed management can also be mentioned -- that of analysis of the present situation -- a planning objective under which this study falls.

In the Eel River Basin, the specific objectives of watershed management should be:

1. To control the production of sediment.

2. To make maximum hydrologic use of the soil mantle and vegetative cover.

3. To yield the maximum harvest of vegetation, consistent with Items 1 and 2 above, and in a manner compatible with man's desires and economic needs.

In accordance with these objectives, the investigation will attempt to serve the following functions:

1. To explore the present and past effects of land use on hydrology and the water-related resources in the Eel River watershed.

2. To postulate how these may be altered in the future.

3. To predict effects of land use upon proposed water development features of The California Water Plan.

4. To summarize the programs and responsibilities of the federal and state agencies most directly concerned.

5. To conclude what steps might be profitably taken to accomplish the desired ends.

In summary, watershed management simply concerns itself with the way in which water comes off the land, and the effect this may have on the

related resources. In man's attempt to control this portion of the hydrologic cycle, watershed management has evolved to fill the voids not covered by other sciences, and to tie together parts of various disciplines which touch on this subject. Some of these disciplines are engineering, forestry, and the soil. sciences. It should be evident that in the history of American resource development, no one profession or group has been in a position to take such an interdisciplinary approach. Historically, watershed management has been of interest to agricultural scientists and resource economists, alternately scorned and accepted by engineers, and almost universally espoused by both technical and lay conservationists. The subject has engendered a great deal of controversy and emotion; and only in the past few years has it assumed a semblance of order.

The Eel River watershed, 3,700 square miles in area, lies in northwestern California, and is as yet intensively developed only in spots. The opportunity to consider watershed management objectives uniquely presents itself in this drainage. Future plans for the development of water for the State of California call for the conservation of the waters of the Eel River Basin for local and export purposes. It is only fitting and proper that a reconnaissance investigation of watershed management factors important to this development be carried out, and it should be expected in a complete basin investigation of proposed water development.

2. Typical problem area in the Eel River Basin, involving timber, grass, soil, and water; vegetative-type conversion area with gully erosion, bank cutting, and sliding. Somerville Creek near Briceland, Humboldt County.

CHAPTER II. DESCRIPTION OF THE EEL RIVER WATERSHED

In the winter of 1849, Dr. Josiah Gregg, a Missouri physician, led a small and poorly equipped party of adventurers from the Trinity mining country over the Klamath Mountains to the coast, south of Humboldt Bay, and eventually encountered a large, unknown river. Because a small group of Indians were carrying away 'eels' (lampreys) that they had caught in this river, Gregg called it the Eel River. The first stages of pioneering development began a few years later, and today, the Eel River Basin supports a population estimated at 40,000.

This drainage lies in northwestern California[1/] in parts of Humboldt, Mendocino, Lake, Trinity, and Glenn Counties, as shown on Plate 1, "Location of Eel River Watershed." It borders both Colusa and Tehama Counties but does not drain any part of them. The basin is 3,684 square miles in area[2/], and varies in elevation from sea level at its mouth to 7,581 feet at Solomon Peak in Trinity County. From its source on the slopes of Bald Mountain in Mendocino County, the Eel River flows south through Lake Pillsbury, west to Van Arsdale Reservoir, and thence predominantly northwest for about 100 miles to the Pacific Ocean, at a point about 15 miles south of Eureka. Along its course, it intercepts tributaries at irregular intervals, the major streams being the Middle, North, and South Forks of the Eel River, and the Van Duzen River, draining 753, 283, 690, and 428 square miles, respectively.

The topography of the Eel River watershed is docile-appearing but rugged in detail. Due to a complex geologic history, the basin is an intricate system of ridges separated by drainages, with only occasional outstanding

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1/ Between Longitudes 122° 40' and 124° 30' West, and Latitudes 39° 15, and 40° 45' North.

2/ Areas obtained from data of the Department of Water Resources' current Coordinated Statewide Planning Program.

peaks. Vegetation runs the gamut of elevational and climatic zones, all the way from dense redwoods through mixed conifers and brush to grass, oak, and sub-alpine plant communities. No extensive part of the area is homogeneous with respect to geology, soils, climate, or vegetation.

Development by man has been only spotty. The few mountain valleys have been utilized as farm and ranch land; timber has been harvested heavily in some locations but not at all in others, and vast areas are almost completely inaccessible. Although rainfall varies from 40 to 115 inches per year as shown on Plate 2, "Distribution of Precipitation, Eel River Watershed," it is not uniformly dispersed either in area or in time, with a resulting hodge-podge of soils, vegetation, and human settlement. The climatic classifications within the area are shown on Plate 3, "Climatic Classifications, Eel River Watershed." These are dealt with in more detail in the remainder of this section.

Climate

The climate of the Eel River Basin has been described as Mediterranean with subregional variations. It is characterized by heavy annual rainfall (40-115 inches) concentrated in the winter months, with hot, dry summers. There is snow at the higher elevations on the eastern boundary of the drainage, and although it contributes to the spring streamflow, it is relatively insignificant in relation to the total water resource. Individual factors such as elevation and orientation exert a strong influence on the climate, and correspondingly on the vegetation and soils of the basin. Climatic classifications according to James[3/], modified for purposes of this report, are described below.

3/ James, John W. "Classification of Climate in California," Office Report, State of California, Department of Water Resources, Meteorologic Unit. 33 pp. (typed) January 1959.

Mediterranean Cool Summer With Fog

This is the well known "fog belt" in which the famous coast redwoods are found. The belt extends from the mouth of the Eel River in a band southward, varying in width, finally narrowing down and leaving the drainage west of Willits. Moderate and uniform temperatures prevail in this belt. Average annual temperatures vary between 50 to 55 degrees Fahrenheit; average summer temperatures are less than 72 degrees Fahrenheit. The heaviest rainfall in the watershed occurs in this belt at the headwaters of Bull Creek, averaging about 115 inches per year. Snow seldom occurs in this zone. Fogs reduce the incoming radiation and increase the precipitation efficiency in this zone. The normal rainfall is added to by a phenomenon known as "fog drip," wherein fog particles condense on vegetation, and drop to the ground, adding to the total precipitation. This effect is not measured in precipitation monitoring programs, and can actually, in some cases, be quite a significant part of the total precipitation received[4/].

Two notable variations in this general class of climate occur. The first is the "temperate rainforest" or "monsoon" type[5/], whereby rainfall is so heavy during the winter months that sufficient moisture is maintained during the summer to support a "rainforest" type of vegetation. The second is the "light fog" belt, which established the range of coast redwood up the river valleys, but out of the fog belt proper. Typically, this fog occurs in lower elevations on summer mornings, and is strongly influenced by northwestern winds. It is dissipated by incoming radiation as the day progresses, usually being

4/ Hopkins, Walt. "Looking Ahead." "North Coast Water and Watersheds." Arcata Research Review. U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. 13 pp. (mimeographed) February 26, 1960.

5/ Not to be confused or associated with the Monsoons characteristic of the Indian Ocean.

completely gone by noon. This is shown on the climatic map as synonymous with the interior range of redwood.

Mediterranean Cool Summer Without Fog

This zone lies directly east of the fog belt, and covers most of the Eel River drainage. Because of the effect of topography upon precipitation distribution, precipitation varies from about 40 inches to 80 inches, occurring for the most part in the winter months. Although most of the area receives some snow, it accumulates only at the higher elevations in the eastern part of the basin. Summers in this zone are usually hot and dry.

Mediterranean Warm Summer

This situation occurs in some of the mountain valleys, and in an oval-shaped area around Alderpoint. This climate is similar to that found over most of the Sacramento and San Joaquin Valleys, but with a greater amount of winter precipitation.

In summary, the climate of the Eel River Basin is of a Mediterranean type, albeit with variations from the monsoon-rainforest-fog belt (along the western boundary) to the hot dry summer conditions (Round Valley, for example). Local conditions of elevation and exposure have a pronounced influence on local climate, and the soils and vegetation found in the area.

Geology

The Eel River Basin lies within the Northern Coast Ranges geomorphic province and comprises some of the most inaccessible and geologically least explored regions of the State. Topographically the province is characterized by elongated, northwest-trending ridges and valleys which are controlled by the underlying geologic structure. The drainage pattern is markedly trellis --

that is, the major streams are parallel to the structural grain of the area. Zones of weakness such as faults or crush zones are commonly important factors in the development of major drainage channels.

Virtually the entire drainage basin is underlain by rocks of the Franciscan formation, with several relatively small areas underlain by upper Cretaceous and Tertiary sediments, particularly in the Eel River Valley. Rocks assigned to the Franciscan formation range in age from late Jurassic to late Cretaceous. The formation is known to be at least 25,000 feet thick, although neither the base nor the top has been recognized. Structually, the Franciscan formation has an extremely disordered appearance. The rocks have been so folded, shattered, and sheared that nearly every outcrop presents some structural complexity. In addition, Franciscan rock units occur characteristically in discontinuous lens-shaped bodies and present at first glance a nearly chaotic mass. Major structural features, as well as belts of rock units or rock assembleges, are mappable and locally may be quite continuous. The prevalent orientation of Franciscan units in the Eel River Basin is roughly North 30 degrees West with an eastward dip. The gross structures seem to consist of open folds cut by strike-slip faults which are nearly parallel to the fold axis. Major faults form wide zones containing blocks of competent rock in a sheared ground mass.

The Franciscan formation is generally divided into three broad belts -- the Coastal, Central, and the Eastern or Metamorphosed belt. The Coastal belt is believed to be the youngest, probably of Cretaceous age, and consists predominantly of unmetamorphosed sedimentary rock. Sandstone, shale, and conglomerate constitute about 95 percent of the entire unit.

The Central Franciscan belt consists of a great variety of rock types in an extremely complex structure. In addition to sandstone, shale, conglomerate, and greenstone, other rock types are dispersed throughout the belt. Chert, limestone, glaucophane schist, serpentine, and associated ultrabasic rock are widespread, but constitute a small portion of the whole.

The Metamorphosed, or the Eastern belt, appears to contain mildly metamorphosed equivalents of the Coastal belt. Most common rock types are slate, phyllite, quartz-mica schist, and foliated sandstone. Igneous rock is generally scarce but may attain considerable importance locally.

The unsorted and angular nature of sedimentary grains in the Franciscan formation and the discontinuity of rock units indicates deposition in a turbulent, rapidly sinking submarine trough. Sporadic submarine volcanic activity occurred, as evidenced by widely distributed greenstone and chert lenses throughout the Central Franciscan belt.

The deposition of sediments took place in late Jurassic and continued into the Cretaceous period. Near the end of the Cretaceous period, uplift took place, accompanied by strong compressional forces resulting in northwest-trending folds and faults. Uplift and erosion continued throughout Cenozoic time, although there was periodic marine encroachment as evidenced by Tertiary marine sediments in the Eureka and Covelo areas, as well as on a lesser scale in several other isolated localities. A very active period of mountain building took place in Miocene time followed by equally active uplift in the Pliocene and

Pleistocene. These later uplifts shaped the topography of the basin as we see it today. Evidence of recent uplift can be traced throughout the Northern Coast Ranges. It is particularly apparent along the coast, where marine terraces have been elevated hundreds of feet above sea level, and along major stream canyons where remnants of old terraces are still discernible high above the present stream channels.

Although the geologic history of the Eel River area is imperfectly known, and disputed, the following chronology can be drawn based on recently published references:[6]

Mesozoic

Late Jurassic to Late Cretaceous 140 to 60 million years ago	1. Deposition of Franciscan sediments in a northwest-trending, rapidly sinking submarine trough. The central tectonically active portion of the trough experienced sporadic volcanic activity and intrusion by ultrabasic igneous rock.
	2. By late Cretaceous time, the great trough containing Franciscan and Cretaceous rocks was filled and an intense period of mountain building took place. The rocks were folded, faulted, and uplifted above sea level.

Cenozoic

60 million years ago to present	The Cenozoic history of the Eel River area, including the Miocene, Pliocene, and Pleistocene epochs, is one of erosion of an emergent land mass, interrupted locally by narrow marine encroachment.

6/ Partially excerpted from: Rice, Salem J. "Geologic Sketch of the Northern Coast Ranges." State of California, Division of Mines, Mineral Information Service, 14:1. January 1961.

Late Miocene 15 million years ago	A severe period of deformation and uplift took place, elevating the mountains to nearly their present form. The Eel River valley area was depressed below sea level and accumulated a thick section of sediments.
Pliocene to Early Pleistocene 13 to 1 million years ago	Minor warping and uplift continued throughout the area. Small interior basins were formed by down-dropping of fault blocks and were filled with sediments.
Middle Pleistocene Less than 1 million years ago	Nearly the entire Eel River area was subjected to regional uplift as evidenced by numerous elevated terraces along the coast.
Present	Continued erosion of the uplifted landmass.

Landsliding on both a large and small scale is widespread throughout the Eel River Basin. The terrain, underlain by severely folded, faulted, and crushed rock, is prone to a distinct type of landsliding -- the earthflow. The depth of an earthflow is generally quite shallow as compared to its areal extent, and resistent knobs of inplace bedrock commonly protrude through the slide debris. Continuous downslope movement has caused a greater accumulation of landslide material near the stream channels than at ridgetops. Upon attainment of sufficient depth of debris a rotational slump often occurs, initiating more sliding from above. An alternate or augmenting cause of slumping can be bank cutting by high stages of rivers, upsetting the stability of the lower portion of the potential slide. Large scale sliding is well illustrated along the Eel River Canyon, where it is characterized by nearly continuous quasi-stable, grass-covered slopes.

The total volume of unstable material along the slopes of the major streams in the basin is so great that it constitutes a major hazard

to potential reservoir construction. Large scale sliding could reduce the storage capacity of several proposed reservoirs by as much as 10 percent. In the design of these dams, possibility of landslides should be taken into account to minimize the possibility of overtopping by wave action.

This present instability of slopes in the Eel River Basin is due primarily to four factors: (1) the fractured nature of the underlying Franciscan rocks, particularly shale; (2) the deep chemical weathering, producing thick soils which become saturated and unstable from heavy rains; (3) the presence of major fault and shear zones which commonly parallel the stream canyons; and (4) the young nature of the topography, with deeply incised canyons due to recent uplifts, all tributaries not yet being "at grade."

The thickest and most extensive accumulation of soil and slope wash is found in areas underlain by crushed, incompetent material such as sheared shale or zones of faulting which can often be traced for considerable distances by topographic expression and characteristic cover of grass-covered soil. Near the tops of the ridges, weathering has progressed to a considerable depth and thick deposits of residual soil are common. In contrast to the semistable side slopes, areas of residual soil are generally quite stable and are covered by dense vegetation.

The underlying consolidated rocks of the Eel River Basin do not contain extensive quantities of ground water. However, ground water basins in the Eel River area are formed by four alluviated valleys -- the Eel River Valley, Round Valley, Little Lake Valley, and Laytonville Valley. They are controlled by faulting in the bedrock, that is, they are down-dropped

blocks, or grabens, filled with unconsolidated Recent alluvium and lake deposits. The surface evidence of faulting has been subsequently all but destroyed by erosion and alluviation. Although Recent alluvium is the most important source of ground water in the Eel River Valley, ground water is also obtained from older sediments of Tertiary age which generally contain less productive aquifers.

Thus, in summary the Eel River Basin is a complex system of ridges and valleys, formed by prominent northwest-southeast orientation of the geologic structure. The majority of the rocks are sedimentaries of the Franciscan formation. Because of the properties of these rocks, there are very few aquifers of importance, with the exception of alluvial materials in the few valleys. Slides have developed on soils derived from weathering of the Franciscan formation, and they comprise a distinctive portion of the landscape. Due to the youthful stage of topographic development within the Eel River Basin, extensive earth movements will continue to occur. The geology is extremely complex and erratic. Much additional study remains before it will be completely understood. However, it is possible that minor earth movements confined to the soil zone could be retarded by proper watershed management techniques.

A map of the "General Geology, Eel River Watershed" is shown in Plate 4.

Soils

The water conservation characteristics of the soils of the Eel River Basin are outstanding as compared to many other mountainous areas of the State. As might be reasonably expected, the soils are closely related to the parent

geology. They are generally of moderate depth and texture and overlie shattered parent rock. However, both the soils and rocks demonstrate good infiltration rates and water-holding capacities. The infiltration rate of the soil and the soil stability are particularly enhanced by the vegetative cover that exists under the local moderate to high rainfall conditions.

In describing the soils of the area, it must be pointed out that due to differences in parent material, slope of the land, microclimate, and vegetation, many different soils exist. However, the Hugo, Josephine, Laughlin, and Maymen Soil Series are by far the most predominant, even though these rarely occur in large, uniform bodies.

For the purposes of this report, the Hugo and Josephine Soil Series may be considered identical. They are the forest soils of the area, and are moderately deep to deep, medium textured, formed from sedimentary rocks and are usually found on moderately to steeply sloping lands. The water-holding capacity of these soils is medium to high, with both soil and parent material usually having good infiltration characteristics. Under native conditions (conifer covered) these soils are stable.

The Laughlin Series represents the soils of the oak-grass "prairie" areas -- more or less open areas, usually found on ridge tops or on similar moderately sloping lands. These areas have soils that were formed in place on the parent rock and should not be confused with the valley fill areas which may also have oak-grass cover. The soils average about 24 inches in depth, are medium textured, and were formed from sedimentary rocks. The water-holding capacity is medium. However, due to shallower depths, the total moisture retention is less than that found in the Hugo or Josephine Series. Under their native grass and oak cover, these soils are fairly stable.

The Maymen Series is the soil most commonly found on the brush lands. It is extremely shallow, was formed from shattered sedimentary rocks, is medium textured, and occurs on steeply sloping land. The total moisture retention capacity of the soil is low due to the shallowness. However, the good permeability of the underlying rock material results in the fairly good water conservation characteristic of these lands. The fact that many plant roots are found deep in the shattered rock further attests to the relatively good water-holding capacity. Theoretically, a soil having only brush as a cover should be readily susceptible to erosion. This conclusion would be based on the consideration of the basic soil properties and the fact that this kind of vegetation deposits a relatively limited amount of litter on the soil surface. However, in this area of high rainfall, a condition has developed that retards sheet erosion. The Maymen soil contains a large quantity of gravel-size rock material throughout the profile. After a few inches of surface soil have been eroded, the gravel remains, resulting in an "erosion pavement." This surface layer of gravel tends to stabilize the remaining soil by absorbing the energy of the falling raindrops and slowing down the lateral flow of water. Undoubtedly, the vegetative cover contributes to this effect also.

As indicated above, the water conservation characteristics of the soils and the native soil stability are generally good in this area. However, this picture is often changed through man's use of the land. There is much evidence throughout the area of soils which have eroded as a result of improperly constructed roads, lumbering practices, and grazing of the range. Under extremes of these uses, any and all of the soils found in the area will erode.

Fire is also a contributing factor to the occurrence of soil erosion. The destruction of protective vegetation and litter and the degradation of the soil structure decreases the infiltration rate, with corresponding sheet erosion of varying severity. As in all cases of sheet erosion, the severity is a function of many variables, such as the slope of the lands, the soil structure and texture, the intensity of the rainfall, vegetative cover, etc..

A <u>general</u> rating of the soils as to relative erodibility under circumstances of use would be of limited usefulness in planning for a specific use in a particular area. A rating would be useful when planning a controlled burn for the improvement of the range. In such cases, a <u>detailed</u> study of the area concerned should be made. General descriptive ratings for most of the soils in the Eel River Basin are available in the published results of the soil-vegetation survey. Ratings vary from "slight" to "high."

The Hugo, Josephine, Laughlin, and Maymen Soil Series have been pointed out as being those most commonly found in the area. Of the many Soil Series less frequently encountered, the Yorkville has a particular characteristic that makes its inclusion in a discussion of this nature important. This characteristic is its inherent lack of stability even under native conditions. With respect to native cover and relief, the Yorkville is similar to the Laughlin Soil, that is, it commonly has grass or oak-grass cover and is found on moderately sloping land. It differs

in that it has a well developed claypan and was developed from relatively impermeable igneous rock. Having a good infiltration rate, it absorbs water fairly rapidly. However, the presence of the claypan impedes the downward movement of water causing the profile to become saturated. When this occurs, the result is quite commonly a localized landslide. Areas of this soil are quite easily recognized by the characteristically irregular land surface. The sod developed by the heavy growth of native grasses tends to hold the surface of the transported soil mass sufficiently intact minimizing sheet and gully erosion.

The Atwell Series is similar to the Yorkville, differing in dominant vegetation (timber) and site (lower slopes of canyons). It, too, has a tendency to slide, is formed on sedimentary rocks, and has a high water-holding capacity.

In areas where a stream passes through a body of Yorkville soil, many slides move directly into the stream. Conceivably this soil could be one of the largest contributors to the sediments carried by the Eel River. In a cursory examination of soil maps7/ covering the route of the Van Duzen River, it was found that of 11 separate bodies of severely eroded land immediately adjacent to the stream, seven were of Yorkville soil. Three of the remaining were classified as colluvial slide areas, and one was a body of Hugo soil.

7/ "Soil-Vegetation Survey" soil maps prepared by the Pacific Southwest Forest and Range Experiment Station in cooperation with the California Division of Forestry, the University of California, and the California Region of the United States Forest Service. These soil maps cover all of the area with the exception of the Trinity County portion and the National Forest area in Mendocino County. No soils data were found for these excluded areas.

To summarize, the surface soils of the Eel River drainage basin are fairly stable (with some exceptions) and generally have good water conservation characteristics. As is the case almost universally, if the lands are subjected to harsh management or burned, the soils will erode. The Yorkville and Atwell Soil Series, although not of significance area wise, present watershed management problems due to their inherent susceptibility to mass erosion through landslides.

Vegetation

In response to intrinsic climatic and edaphic conditions, vegetation assumes a variety of forms in the Eel River Basin. Almost all extremes are found, from the majestic and lush coast redwood forests to the dry, desolate chaparral stretches in the southern extremes of the drainage.

Inspection of the vegetative cover map, Plate 5, "Distribution of Vegetation, Eel River Watershed," shows four main rough belts of vegetation running in a northwest-southeast direction. The first is the redwood belt in the western and wetter areas. Following this are the Douglas fir, woodland-grass, and mixed conifer belts. Thus, the ocean side and eastern mountain divide are forest, but the central part is mainly grass, woodland, and brush. These, of course, are broad classifications and general statements, but this effect is noticeable to the areal observer.

Each vegetative type, according to the U. S. Forest Service[8/] is discussed in appropriate detail in the following:

Redwood Type

This vegetative type has been described as "forests in which 20 percent or more of the stand is redwood (Sequoia sempervirens)." In the

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8/ U. S. Forest Service. "Map of Vegetative Types of California." California Forest and Range Experiment Station, Berkeley, California. January 1945.

U. S. Forest Service. "Forest Statistics for California." Forest Survey Release No. 25, California Forest and Range Experiment Station, Berkeley,

Eel River Basin, it occupies about 325,000 acres, or 13.7 percent of the total land area. Perhaps no one species of vascular vegetation has received so much reverence, publicity, and research as the California Coast Redwood, with the possible exception of the Bigtree or Giant Sequoia (Sequoia gigantea). As an individual tree, it exhibits a series of properties which makes it valuable as a lumber resource and as a recreational attraction. Redwood land is in demand by the recreationist, who seeks the coolness and contemplation of its groves; by the lumberman for its cellulose production potential and its high quality wood, and by the scientist, who wishes to study the uniqueness of these great trees.

Virgin redwood timber occasionally is found in heights exceeding 300 feet, and is known to occur in volumes approaching one million board-feet per acre. Such stands generally range in age from 500 to 800 years with occasional individual trees exceeding 1,500 years. Upon cutting, redwood can sprout, forming a series of young trees growing from the stump of the old tree, and accumulating a large volume in a short time. Its wood is resistant in different degrees to fire, insects, and rot, and is used to a large extent for siding, fencing, and other outdoor applications.

Recent research in redwood ecology, being carried on by the University of California[9/] presents some evidence that the classic bottomland redwood groves have historically been subjected to periodic flooding and inundation by sediment. According to tree-ring studies, each inundation was followed by a spurt of tree growths, tapering off to the next flood. The buried soil profiles representing these floods have been found to

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9/ Anonymous. "Redwood Ecology Project, Annual Report, 1960." Wildland Research Center, University of California and State of California, Division of Beaches and Parks, Department of Natural Resources. 40 pp. and appendix. 1960.

contain bits of charcoal, suggesting that both fires and floods have been a natural occurrence in the redwood region for the past millenium or so, and that these floods were beneficial to the sequoias.

It is the size and great natural beauty of the redwood trees in place, however, which has drawn world-wide attention (see Photo 3). Early explorer's tales were discounted as spectacular exaggerations, but even modern men respect the enormous size and cathedral-like atmosphere of the bottomland virgin groves. These trees are the Eel River Basin's most well known resource; as a recreational asset their value cannot readily be determined by conventional means. The public desire that outstanding redwood groves be preserved for recreation and as "museum pieces" has been demonstrated by the many privately purchased tracts placed under State management.

Thus, the redwood type, although it contains a number of other species (Douglas Fir, western redcedar, madrone) is quite valuable from the standpoint of both timber production and recreation. It is a unique resource, and should be managed with the utmost care, to assure its permanence and continuous benefit to man.

Douglas Fir Type

This vegetative type has been defined as "areas with Douglas fir comprising more than 80 percent of the commercial conifer cover; or mixtures of Douglas fir and the true firs in which Douglas fir comprises 20 percent or more of the commercial conifer cover." The Douglas fir forest is found directly to the east of the redwood forest, and at medium elevations, reflecting a zone of somewhat lower rainfall and little or no fog. In the

Division of Beaches and Parks Photograph

3. Interior of a coast redwood grove on river bottomland, Humboldt County.

Eel River Basin, it comprises 520,000 acres, or 22.1 percent of the total land area. In past years, this was considered an inferior forest type, but recently it has been utilized heavily where accessible. The Douglas fir forest attains its best development in California from Mendocino County northward, especially on north and east slopes, where it sometimes forms dense pure stands[10].

Portions of the Douglas fir forests of this area are sometimes included with redwood in different classifications. In combination, they represent the largest portion of timber growth potential in the basin. The following statement has been made concerning the ability of this mixture to produce timber:

> "Its capacity for growing wood sets the redwood-Douglas fir region apart from others. The forests of this region are among the fastest growing in the world. On the more favorable sites both redwood and its associated species grow remarkably fast. High sites in the redwood type will grow a minimum of 600 board feet per acre per year, and the better sites which are well stocked with young timber will produce more than 1,000 board feet per year...."[11]

Pine-Fir-Douglas Fir (Mixed Conifers) Type

This vegetative type is defined as "areas with mixtures of the commercial pines and/or Douglas fir, incense cedar, and the true firs in which no one species comprises as much as 80 percent of the commercial conifer cover." This group covers about 505,000 acres, or 21.4 percent, of the Eel River Basin. It is scattered through the center of the basin and concentrated along the eastern boundary, typifying National Forest

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10/ Burcham, L. T. "California Range Land." State of California, Division of Forestry, Department of Natural Resources. 261 pp. 1957.

11/ Roy, D. F. "Forest Management Research in the Redwood-Douglas-fir Region of California -- A Summary of Forester's Views on Research Needs." Miscellaneous Paper No. 24, California Forest and Range Experiment Station, U. S. Forest Service, Berkeley. 17 pp. 1958.

timberland. As implied by its name, it is a mixture of different conifers, naturally succeeding itself unless disturbed wholesale by a disaster. A good part of this type constitutes commercial forest, and is presently undergoing initial harvest as such.

Pine Type

This vegetative type is defined as "areas with ponderosa, Jeffrey, or sugar pines comprising more than 80 percent of the commercial conifer cover." It constitutes about 32,000 acres, or 1.3 percent, of the area in scattered tracts in the Eel River Basin. This, too, is a commercial forest type, although due to its magnitude of lesser importance in the study area.

Fir Type

The fir type is described as "areas with true firs comprising more than 80 percent of the commercial conifer cover." This type occupies only 26,000 acres, or 1.1 percent, of the land area in the Eel River Basin. It is found only at the higher elevations on the eastern boundary, and it is of relatively minor importance.

Minor Conifer Type

Only one area of this type, comprising about 21,000 acres (0.9 percent), is found in the Eel River Basin. It is located in the southern part of the drainage on the slopes of Elk Creek, tributary to the Middle Fork Eel River. This cover is mainly Sargent Cypress (Cupressus Sargentii) and is worthy of mention only in passing.

Woodland and Woodland-Grass Type

These two plant communities are dealt with in one discussion

because of their similarities. They are alike in that the dominant vegetative feature is hardwood trees (oak, madrone, tanoak, maple, etc.), and are only different in the composition of secondary vegetation. These distinctions[12] are in fact, not made by some workers, the woodland-grass component being divided into woodland and grass. In many areas, they are contiguous, but are not necessarily so. Typical species are Oregon oak, California black oak, tanoak, madrone, maple, Oregon ash, and alder. Secondary vegetation can include herbaceous vegetation, including grasses, and some conifers. These two vegetative groups together form a discontinuous belt up the central axis of the drainage. It provides range forage second in unit amounts only to the pure grassland type, and occurs in almost all situations except in direct mixture with redwoods.

In the Eel River Basin, its areas are as follows:

	Area (Square Miles)	Percent of Total Land Area
Woodland	139.3	3.8
Woodland-grass	785.4	21.3
Total	924.7	25.1

Chaparral Type

Defined simply as "areas with such shrubs as manzanitas, scrub oaks, and chamise covering more than 50 percent of the ground," this plant community is often found in Mediterranean type climates on dryer sites in foothill and mountain regions. Its dominant constituents are evergreen and extensively branched shrubs in great variety.

12/ U. S. Forest Service. "Forest Statistics for California." Forest Survey Release No. 25, California Forest and Range Experiment Station, Berkeley, California. 63 pp. 1954.

In the Eel River Basin, it covers 175,000 acres, or 7.5 percent of the total land area, predominantly in the southeastern parts of the drainage. This is the northernmost outpost of chaparral in the Coast Range. It is much more widespread and of much greater importance in the Southern Coast Range and the Transverse Range in Southern California, where it is of great value as an erosion retarding watershed cover.

Depending, of course, upon the exact botanical composition of an individual plant community, chaparrel tends to replace itself after a fire. Individual species which comprise the association are either heavy and prolific seeders, or vigorous sprouters, or both.

Although some controversy exists over the causes of chaparral occurrence, many contend it is a completely natural effect, and is nothing more than a vegetative reflection of the site. Chaparral has been pointed out by some as being the result of past fire, implying that without this occurrence, it would not exist. However, the presence of chaparral has been documented from the earliest records of exploration in California, even though certain of the chaparral species are recognized as pioneer or secondary vegetation under different conditions.

Chaparral lands are usually of low agricultural value. In utilizing them, a unit of chaparral will produce roughly only about a tenth the range forage of a comparable unit of grassland. Wildlife, however, makes some use of it, again depending upon the exact composition and condition of the community.

As mentioned by Burcham,[13] chaparral mixes somewhat with coniferous forests and oak woodlands, and is more prevalent than usually shown on cover maps. Thus, it can be found to some extent in almost all areas of the Eel River Basin, even in the redwood belt.

<u>Grass Type</u>

Extensive but discontinuous areas of grassland exist in the Eel River Basin. This has been described by Burcham[13] as the "north coastal prairie," and it undoubtedly contains some range lands which have been converted to grass from brush or timber. To a visitor unfamiliar with the North Coastal area, the grass appears to be an anomoly, as it occurs sprinkled through areas where one might otherwise expect timber. It is found in areas having rainfall up to 115 inches (annually), as seen on the Honeydew Road at the Bull Creek crest in Humboldt County. These prairies are found on "true grassland soils, closely related to, or identical with, the Great Soil Group known as Prairie Soils . . . . They are stable grassland communities . . . which have been maintained under natural conditions for a very long time."[13] The grasslands are found on ridge tops, on remnants of the Klamath peneplane, on landslide debris topography, on stable side slopes, and occasionally in bottoms.

The Gregg party in 1849-50 found them an oasis in the timber, as they were a source of forage and game in a seemingly sterile forest. L. K. Wood, a member of the party, commented on them as follows, a number of years later:

13/ Burcham, L. T. "California Range Land." State of California, Division of Forestry, Department of Natural Resources. 261 pp. 1957.

"Again we had the good fortune to reach a piece of mountain prairie, where we found an abundance of game for ourselves, and plenty of grass for our animals."14/

At this point in their journey, they were in the Klamath River drainage, but the remarks are representative of their attitudes towards the grasslands throughout the entire trip, which eventually followed the South Fork Eel River to near its source.

Numerous changes in density and composition caused by use and the introduction of exotic annuals have altered the potential of the original grasslands considerably, the precise changes not being known.

Throughout the Eel River Basin, pure grasslands cover about 72,000 acres, or 3.0 percent of the total land, constituting a range resource of considerable magnitude. Because of the nature of the data from which the vegetative areas are derived, much grasslands in small parcels are found interspersed with timber types and therefore not included in the grasslands areal estimate.

The areal distribution of vegetative types in the Eel River Basin is presented in Table 1 (page 35).

Hydrology

In connection with water project planning activities under the department's North Coastal Area Investigation, the hydrology of the Eel River and the North Coastal streams has been studied in some detail.

Precipitation in the Eel River Basin averages about 60 inches annually, most of which is in the form of low intensity winter and spring rains. Although there is snow along the eastern divide, it is of small consequence in relation to the total water resource. Precipitation is

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14/ Anonymous. "History of Humboldt County, California, with Illustrations." W. Elliott & Company, San Francisco. 218 pp. 1881.

TABLE 1

AREAL DISTRIBUTION OF VEGETATIVE TYPES IN THE EEL RIVER BASIN

Type	Area (square miles)	Percent of total area
Redwood	505.1	13.7
Douglas fir	813.4	22.1
Pine-fir-Douglas fir (mixed conifers)	788.0	21.4
Pine	49.4	1.3
Fir	40.9	1.1
Subtotal	2196.8	59.6
Minor conifer	32.0	0.9
Woodland	139.3	3.8
Chaparral	274.9	7.5
Coastal sage	22.8	0.6
Subtotal	469.0	12.8
Woodland-grass	785.4	21.3
Grass	112.0	3.0
Subtotal	897.4	24.3
Urban - cultivated	120.8	3.3
Subtotal	120.8	3.3
TOTAL	3684.0	100.0

Source: Planimetered areas from Weislander's Vegetative Map. U. S. Forest Service. "Map of Vegetative Types of California," California Forest and Range Experiment Station, Berkeley, California. January 1945.

not uniformly distributed either in time or in place, exhibiting considerable variation from year to year and from place to place. For example, historical annual precipitation at Willits has varied from 18.55 to 97.16 inches; at Branscomb from 46.12 to 132.62 inches; and 38.67 to 135.02 inches at Laytonville. Typically, the first seasonal rains begin in late September or October, a maximum occurs from December to February, and the last rains fall in late May or early June. Rainfall in late June, July, August, or early September is rare and of small consequence.

Runoff from the Eel River Basin approximates an average of 31 inches annually, or roughly 6,300,000 acre-feet. Because of the relative lack of snow and of natural storage, streamflow is highly responsive to rainfall. The runoff pattern, therefore, corresponds to the rainfall pattern, and there are two distinct hydrologic seasons -- a wet season and a dry season. The wet, or flood season, begins with the first major fall rains and continues through to late May or early June. The dry season extends through the interim. Many streams which flow continuously through the winter dry up almost completely during the summer months, and the areas are in effect waterless. Certain tributary streams rage in flood during the winter rains, and dry out to a series of pools during the late summer. Thus, there is a period of from three to five months annually in which all streamflow must be supplied from ground water accretions, channel storage, snowmelt, or reservoir storage. Vegetation in this dry season must struggle harder with the passage of time to pry water from the soil, annual grasses cure, and with the decrease of humidity, the fire hazard increases.

Recorded flows at Scotia have varied from 10 second-feet to 541,000 second-feet and natural yields at Scotia from 868,000 acre-feet ($4\frac{1}{2}$ inches of runoff) to 11,669,000 acre-feet (59 inches of runnoff) annually. Runoff is controlled to a minor extent by Scott Dam (Lake Pillsbury) on the upper main stem of the Eel River, with a storage of about 92,000 acre-feet, and through diversion from Lake Pillsbury storage at Van Arsdale Dam through the Pacific Gas and Electric Company's Potter Valley Tunnel into the Russian River drainage. Lake Pillsbury is the only significant reservoir storage in the basin. Diversions from it, largely for power purposes, have been in the neighborhood of 200,000 acre-feet annually for the past few years.

There are numerous small natural lakes and ponds in the drainage and a few small man-made ranch and farm reservoirs. The natural ponds are usually quite limited in size, covering less than a few acres, and seldom of a permanent nature. During the summer there is little natural inflow to these lakes and, as the season progresses, they tend to dry out to little more than stagnant pools. The drainage area of a typical pond is quite small, usually in a landslide pocket, a great many possessing less than an acre of water surface. These are not shown on standard topographic maps. Their occurrence appears to be limited almost entirely to the eastern and central belts of mountainous topography. Their effect on the hydrology of the entire basin is unknown, but is thought to be insignificant.

The Eel River System has had an infamous reputation for flooding since its earliest exploration. Gregg's party in the winter of 1849-50 was greatly inconvenienced by high waters, and 31 years later, in the first written history of Humboldt County, the following statement was made:

> "The current during the season of floods is terrific. The canons are then but conduits for the seething flood, bearing on

its surface the debris of the forest's huge redwood trees, undermined along the banks and swept along by the flood; old logs dislodged from the drifts, where they had lain for years, are carried out into the ocean. These rivers rise very suddenly with heavy rain in the winter. "15/

This periodic occurrence of damaging floods constitutes the most serious water problem of the basin. Major floods occurred in 1907, 1938, 1950, 1955, and 1964, the latter two causing damages estimated at over 22 and 50 million dollars respectively. The 1964 flood was the greatest on record, and caused 19 deaths and widespread destruction to urban areas, farmlands, lumber mills, and transportation facilities. Several communities were completely destroyed. Because of the lack of transportation for logs and cut lumber, several thousand workers were without jobs.

A need also exists for improving the meager streamflow during the summer months for the enhancement of fish habitat and improvement of recreation facilities.

Despite the lack of rainfall in summer months, portions of the northwestern extremes of the Eel River Basin are unusually well watered. Being one of the wettest places in the State, it was recognized in its early settling as possessing the asset of abundant water. The following quotation, almost poetic, eulogized this 81 years ago:

"One of the features of Humboldt County is its wealth in pure water. One finds it everywhere -- pure and cold as the fountains of the upper Sierra. An old resident says there is not, he thinks, 160 acres in the county without a permanent spring of fine water. The springs of pure, cold water about this county are a marvel, and it is impossible to fully describe their beauty and usefulness. There are thousands and thousands. Every hill and mountain side teems with them and the weary traveller and his thirsty beast find streams of pure water, cool and fresh, gushing from the wayside banks, and gathered into troughs for his convenience. The flow of these springs varies from a few gallons a day to barrels per minute. "15/

15/ Anonymous. "History of Humboldt County, California, with Illustrations." W. Elliott & Company, San Francisco. 218 pp. 1881.

Water Quality

The Eel River and its tributaries flow primarily through the Franciscan formation consisting of sandstone, shale, conglomerate, greenstone, chert, and minor amounts of limestone and schist. As these rocks contain a relatively low percentage of readily soluable minerals and the area is one of heavy rainfall, resultant runoff carries low concentrations of dissolved solids and is calcium bicarbonate in character.

The most downstream permanent monthly sampling station on the Eel River is located at Scotia, approximately 12 miles above the mouth of the river. Analyses of monthly grab samples collected at this station since April 1951, show the following variation in significant mineral quality characteristics: total dissolved solids, from 57 to 254 parts per million; hardness, from 43 to 212 parts per million; boron, 0.0 to 0.48 parts per million; and percent sodium, from 9 to 26 percent. An average value of the above ranges (weighted according to flow) would fall much closer to the minimum than the maximum figures. Water with the above characteristics is of excellent mineral quality and would be desirable for nearly all beneficial uses.

Major tributaries of the Eel River supply water of equal or even slightly better mineral quality. One notable exception to the excellent mineral quality of the surface water in the Eel River watershed is the presence of high concentrations of boron during periods of low flow in the upper reaches of the Eel River. For example, Outlet Creek near Longvale, although low in total dissolved solids, has shown concentrations of boron as high as 3.4 parts per million. In September of 1960, a sampling reconnaissance was made of Outlet Creek and its tributaries in an attempt

to locate more accurately the source of the high boron concentrations. Results of this limited survey indicated that most of the boron in Outlet Creek was coming from Long Valley Creek which carried 9.9 parts per million boron just above its confluence with Outlet Creek. Although no further attempt was made to pinpoint the source of the boron, it is probable that it is supplied to Long Valley Creek by volcanic or deep-seated waters from one or more springs similar to those that have been identified in the nearby Clear Lake area. A fault zone is known to exist in the vicinity of Long Valley Creek, and waters with high boron contents have often been associated with such fracture zones.

Boron concentrations as high as 20 parts per million are not considered deleterious to a drinking water supply. However, a boron content of more than 2.0 parts per million in irrigation water generally is considered injurious to unsatisfactory for most crops under most conditions. Streams with such high concentrations of boron as Outlet Creek, however, supply a small portion of the total Eel River discharge. Thus, after joining other tributaries or the main stem of the Eel River, water from such streams is soon diluted so that boron concentrations seldom exceed 0.5 parts per million. Any impoundment of such streams, consisting of a mixture of high and low flows, should result in a water that would be Class 1 for irrigation and of excellent mineral quality for all other prevalent beneficial uses.

During periods of intense rainfall and flooding, the suspended sediment load in the Eel River and many of its tributaries is high due to the rugged topography and steep gradients prevalent throughout the watershed. In some areas unstable soils add to this problem by increasing the suspended sediment load and turbidity. During periods of high turbidity the waters are unsuitable for many uses without receiving treatment.

One of the greatest threats to the quality of Eel River water would be the uncontrolled development of the Eel River watershed. Careless construction and land clearing practices can result in both immediate and long-term impairment such as increasing erosion, clear waters becoming turbid, and spawning gravels being clogged with sediments. Increased sediment loads will also decrease the storage capacity in reservoirs to be constructed and shorten their useful lives. Thus, as the great forest resources of this area are developed and harvested, it is important that only the best forestry practices be utilized in order that water quality impairment be minimized.

During the winter months the temperature of the Eel River water drops to around 40° F., but in the late summer months it often exceeds 80° F.

Fish and Wildlife

The Eel River system provides essential habitat for substantial populations of economically important fish and wildlife species. These populations contribute substantially to the recreation service industry of the area. The king and silver salmon populations that utilize the river and its many tributaries for spawning and early growth contribute significantly to the commercial fishing industry of northwestern California.

Fishes

The most important fishes are king salmon, silver salmon, steelhead trout (migratory), and rainbow trout (nonmigratory). Several additional fishes reside in the system, or use it for spawning. However, they are of little consequence to the economy of the area.

King salmon utilize the Eel River system for reproduction and a few months of early growth only. The remainder of their life cycle, which is most commonly three or four years, but may vary from one to seven, is spent in the Pacific Ocean. The annual spawning migration of king salmon in the Eel River commences during late August and early September, when the adults arrive in the Fernbridge area to await the higher flows needed for further upstream migration. In low-flow years, these early arrivals are forced to spawn on riffles in the lower portion of the main stem of the river or in the lower tributaries, such as the Van Duzen River.

The bulk of the annual spawning run occurs during late October and early November, depending upon the advent of fall precipitation. Actual spawning begins in late October, peaks in November, and tapers off through December to early January. Downstream migration of juvenile king salmon is heaviest during the following June. Most of the young fish move from the estuaries to the ocean during July and August of the same year.

It is estimated that the average spawning run of adult king salmon in the Eel River system over a 25-year period from 1938 to 1962 was approximately 69,000 fish, with an estimated high of 177,000 in a single year. This estimate is based on annual counts of salmon passage over Benbow Dam on the South Fork Eel River, and escapement estimates made by the U. S. Fish and Wildlife Service for the entire river during the period 1955-59.

Silver salmon use the Eel River system for a full year of juvenile growth, in addition to spawning. Most adults mature as three-year-olds, after spending two years in the ocean. The annual spawning migration in the Eel River commences in October, reaches a high in November, and continues through December. Egg deposition begins in late November, and continues

through December and January. The bulk of silver salmon spawning occurs in small tributaries and the headwaters of the larger Eel River tributaries.

The average annual silver salmon spawning migration run for the period 1938-62 is estimated at approximately 30,000 fish.

Steelhead trout are the most abundant anadromous species in the Eel River and are most dependent upon the fresh water stream habitat. The adults enter the river during all months of the year. However, the heaviest migration occurs during December and January. Spawning occurs during February, March, and April in the headwaters of the system. Little, if any, steelhead reproduction takes place in the main stem of the river.

Juvenile steelhead may spend from one to four years in their natal stream before moving downstream to the ocean. Some young steelhead remain in the Eel River for their complete life span. These nonmigrants provide much of the summer "trout" angling in the watershed. An average of about 115,000 steelhead adults entered the Eel River during the period 1938-62.

Resident rainbow trout are most abundant in the headwaters of the drainage, particularly in the inaccessible portions of the drainage. These populations support a moderate amount of angling during the summer months in relatively accessible areas, thereby contributing to the recreation industry of the Eel River area. However, by far the major portion of the summer "trout" fishery is supported by juvenile steelhead.

The future development of water resources within the Eel River Basin could have a variety of effects both desirable and undesirable on

fishery resources, depending upon the adequacy of water project planning. Headwater projects with adequate features for fish could result in a substantial increase, particularly in king salmon. Projects located in the lower portions of the system would be potentially damaging, and large hatcheries might be necessary to preserve the existing fisheries resources.

The California Department of Fish and Game points out that the Eel River system possesses a remarkable potential for an increase in the production of salmon and steelhead. It will be necessary to realize most of this potential if the future demand for recreation and commercially produced salmon in the State is going to be met. The economic development of the area is partially dependent upon the realization of this potential.

Wildlife

Although many game species of wildlife exist in the Eel River Basin, only the black-tailed deer is of conceivable importance to watershed management considerations, while concurrently it is the most important game animal. The annual hunting season bolsters the area's economy considerably, although much of the private landholdings are posted against hunting. The deer are largely nonmigratory, except at higher elevations in the Middle Fork Eel River drainage and the Lake Pillsbury area, where snow forces migration to lower elevations during the late fall and winter months. Populations are generally low in the dense redwood and fir forests of the basin, while in the more open plant communities of woodland, woodland-grass, ponderosa pine, and broken chaparral, they are more abundant. Their abundance is controlled by the available food which varies seasonally, and includes mountain mahogany, buckbrush, deerbrush, chamise, manzanita, oak, and incense cedar. Grasses and forbs are important seasonally.

Other game animals include black bear, mountain lions, California and mountain quail, ring-necked pheasants, gray squirrels, brush rabbits, band-tailed pigeons, blue and ruffed grouse, and mourning doves, all of which are hunted to some extent. Although several fur-bearing animals inhabit the drainage, trapping is light and of no appreciable value to the local economy. The commercially important species is mink. Other species include river otter, gray fox, coyote, muskrat, ring-tailed cat, bobcat, fisher, pine marten, racoon, weasel, badger, and skunk.

Definite relationships exist between the fish and wildlife and the soil and vegetation which constitute their habitat. In the Eel River Basin, the actions of land use on the fisheries resource is quite pronounced. This is discussed in more detail elsewhere in this report. The effects of wildlife on soil and vegetation, and vice versa, are less obvious and important, and are discussed briefly herein.

Deer in particular can affect the soil and vegetation in a noticeable manner. They have presented a problem in some portions of the Eel River Basin by browsing on young forest plantations. This will become a more serious problem as the reforestation of cutover areas for sustained yield timber management increases in economic importance. In a restricted portion of the Glenn County portion of the basin, deer have been directly responsible for preventing regrowth of vegetation following earlier overgrazing by livestock, resulting in limited sheet erosion. In other areas, deer have indirectly contributed to the erosion problem by competing with livestock for feed on steeply sloping grasslands.

Land use practices in the Eel River Basin have been largely beneficial to deer. Timber cutting in dense forests often results in increased food for deer by allowing establishment of plant species preferred for browse by deer. Clearing of certain lands for pasture may also have a beneficial effect on deer (and quail) populations by increasing plant food species. On the other hand, much of the private landholdings and access roads are posted against hunting and tresspass, and thus a potential for the control of deer numbers (and for a great amount of recreational use also) is not now being realized. The California Department of Fish and Game has stated that this is a poor situation from the standpoint of deer, as well as the timber and forage resource. A greater harvest of the populations would result in healthier deer herds, better fawn survival, less damage to restocked timber, and less competition with domestic grazing animals.

No significant changes in the wildlife populations of the Eel River Basin are foreseen for many years, despite anticipated economic development. In fact, increased logging activity may result in minor increases in numbers of deer. Quail populations will probably remain relatively static. The small pheasant population may be reduced, due to urbanization of existing lands suitable for grain production.

Economics

The economy of the Eel River Basin has long been dependent upon the development and utilization of its abundant natural resources. Logging, lumber, and manufacture of forest products have been especially important in supporting the population of the area. The timber industry developed soon after initial settlement of the area and quickly became, and has

remained to date, the most important segment of the economy. In recent years, the recreation assets of the Eel River area have ascended to prominence, centering around the world-famous coast redwoods, which attain their maximum size in the basin. Agriculture, predominantly ranching and livestock-oriented activities, was the original impetus for settlement, although it occupies a position of lesser importance at present. Minor industries include marine fisheries and mining. Service industries such as wholesale and retail trade, construction, transportation, communication, and utilities have developed in support of the local economy.

Timber Industries

The excellent conditions for growing redwood and Douglas fir timber in the Eel River Basin have made the forest products industry of primary importance. This industry is concentrated in the redwood belt, and employs about 40 percent of the workers in the area. At present, cutting in the basin is exceeding growth by about two and one-half to three times, as virgin (or overmature) stands are still being harvested. This situation is likely to persist for another 15 to 20 years, after which timber cutting is not expected to exceed net annual growth.

Much of the Douglas fir-redwood land has an exceptional potential for growing commercial timber, at least as compared with other areas of the Western United States. Representative unit growth figures for fully stocked lands under good management can average about 450 board-feet per acre per year. Much of this land is steep and well watered, and all factors considered, trees are its most suitable crop. These lands are generally not conducive to grazing and when so used bring lower returns.

There is good cause to expect that the timber industry will continue to be a permanent feature of the Eel River Basin economy. Studies indicate that under continuous yield management, annual harvest of timber in the Eel River Basin will approximate 650 million board-feet per year, or about $1\frac{1}{2}$ percent of the total national requirement in 1975.

In addition to the production of lumber, which has thus far constituted the majority of timber utilization, other products will be in demand. The pulp and paper industry has only recently begun to demonstrate interest in California's North Coast, and it has historically tended to follow in the wake of a well established lumber industry. There is, in the area, a readily available source of material for pulp use: wood residues, logging residues, and standing timber of the smaller sizes which might be removed in silvicultural operations. With stabilization of the water supply, several pulp and/or paper mills can be expected to be installed in the environs of the lower Eel River in the next several decades.

It is significant that most of the forest lands in the Eel River Basin are in private holdings rather than in national forests, as is the case in most of the commercial forest lands in California. For this reason, logging practices are usually dictated more by near-term financial gain than by governmental control.

The advent of a market for pulp wood should have several effects upon land use. Forestry operations would be intensified because of expected economic returns from short rotation operations, from thinnings, and from more efficient utilization of the larger sizes. Competition of pulpwood sizes with sawlogs for pulp and paper consumption may result in some marginal timber lands being cut.

Two contradictory effects could result from the more intensive use of forest lands. The utilization of marginal lands or poorer timber sites could provoke erosion and/or the invasion of brush. Close attention to better timber sites could result in improved forest conservation practices and consciousness of the value of soil conservation, to the benefit of the site and soil resource.

The present demand for veneer and plywood should continue to increase in volume and in proportion to the total forest products use. This, too, will result in more intensive use of forest lands, with most of the above-mentioned side effects.

Thus, for the forest based segment of the Eel River economy, increasing demands for timber products will require maximum utilization of the basin's forests. Such maximum utilization does not necessarily mean wasteful or destructive logging practices. In fact, the reverse is more apt to be true. If lumber products are to remain competitive with substitute materials, increased efficiencies in forest management are necessary. In addition, competition and anticipated growth in demand for all timber products will necessitate the more complete utilization of raw materials in logging and milling. Such increases in efficiency throughout the industry should prove less detrimental, from a watershed management point of view, than some past and current logging practices.

Besides the economic factors of operation, certain public pressures and public relations are important business considerations. This will become increasingly true in the timber industry as competition increases and demands for multiple uses of land intensify. The reckless use of timber resources is not compatible with either the public's or the industry's best

interest. Some companies have recognized this and have put into effect reforestation and forest management programs. The latter will become more typical and widespread as the timber industry moves toward more efficient operation, including integration. The overall effect with respect to soil and water conservation should be positive.

Recreation

Recreation ranks second to timber as the most important industry in the economy of the Eel River watershed. The diversity of climate, topography, and vegetation, along with good hunting and fishing areas combine to make it extremely attractive to recreationists and tourists. It has, however, lagged in recreation development because of its inconvenient location with respect to major population centers and the relatively slow and inconvenient highway access.

The population growth which has been characteristic of California is expected to continue in the future and, coupled with additional leisure time, this population will seek recreation in various forms in the Eel River Basin. The completion of Highway U. S. 101 to freeway standards should be a positive step towards channeling a larger volume of recreation to the area. Although most of the recreation pressures are and will continue to be in the redwood belt, potential for development in the hinterland exists, but is discouraged to all except the hearty and adventurous at the present time because of a lack of suitable access.

It is assumed that the number of recreation sites and facilities will increase in response to predicted public demand. The development of water projects will be particularly important in this regard. In addition to providing increased recreation opportunities, both at site and downstream, associated road construction will encourage recreational development in the interior of the basin generally.

Most of the uses of land for recreation are nondestructive or even preservational. Generally, only a small amount of the total land allocated for recreation purposes is actually used, albeit this heavily. The construction of additional highway features may cause soil stability problems not now existing, if the present situation can be taken as a sample of things to come. Attention to landscaping and drainage facilities will materially aid in the reduction of erosion and soil loss due to road construction.

Recreation in the Eel River Basin is expected to expand significantly, and should become a greater economic force in determining land use. Undoubtedly, new areas will be added to the State Park System, and new access will develop through National Forests and private lands of the interior. There will be a need to supply clear and abundant water for the fisherman, and to provide convenient transportation to the recreation attractions. The new and improved highways, and the possible water development projects in the Eel River Basin, are the only elements of recreation which might result in significant effects of concern from a watershed management point of view.

Agriculture

The third industry in importance is agriculture, the main activity centering around livestock, with dairying on the better sites in the lower Eel River Delta, and wildland grazing on most of the remaining drainage. Some truck and field crops are raised and several thousands of acres are irrigated in Round Valley, Little Lake Valley, and the lower Eel River area, but the major agricultural effort is ranching.

The best bottomlands in the Eel River Basin are comparable in quality to the best found in the Sacramento and San Joaquin Valleys. The

prairies are generally the best wildland available for grazing in the State, or at least were under pristine conditions.[16] Ranches scattered throughout the mountainous areas attest to its use as range forage, even though the distribution of the grasslands necessitated large holdings to support a family unit.

Future trends will show a decrease in use of the more level and accessible agricultural land due to encroaching urbanization in such areas as the lower Eel River. As a result, some of the less desirable and more hilly lands will probably be utilized to meet increasing local demands. Most of the population increase will probably occur in areas that are now of urban and suburban character. Wildland ranching will probably be little affected by urban encroachment. However, some prime hunting, fishing, and recreational lands will probably become private and public areas dedicated solely to these ends. These developments should have little direct effect upon watershed management.

Other Industries

Other resource based elements of the economy include commercial fishing and minerals. The commercial fishing is mainly in the ocean waters adjacent to the Eel River outlet, but is substantially affected by the salmon produced in the river. There could possibly be effects of developments in the basin which would alter the numbers of fish available for commercial harvest. The industry within the basin is quite limited, the main concentration being in the Eureka-Arcata area. No substantial increase in activity in this endeavor is expected.

16/ Burcham, L. T. "California Range Land." State of California, Division of Forestry, Department of Natural Resources. 261 pp. 1957.

There is a limited mineral industry in the basin, primarily the mining of sand and gravel for construction. As construction is expected to increase, increases of sand and gravel production can be expected to change proportionately. This activity could stir up a good deal of clay-sized sediment which is detrimental to the quality of water, and thus the fish, the recreation, and the water-using industries. Other existing minerals such as clay, natural gas, manganese, copper, coal, chromium, and gold are expected to have little effect on the economy of the basin during the next several decades.

Population

The present population of the Eel River watershed is estimated (1960) at 40,300, of which 28,400 or 70 percent are in Humboldt County, principally in the lower Eel River area. Twenty-eight percent, or 11,450, are in Mendocino County, while the remainder is split between Lake and Trinity Counties. There are believed to be fewer than a half-dozen permanent residents of the Glenn County portion of the drainage.

Population data and future predictions are presented in Table 2, while employment figures by industry are shown in Table 3. In Tables 4 and 5, figures of land ownership in the Eel River Basin by type of ownership, and by counties, respectively, are tabulated.

TABLE 2

POPULATION DATA AND ESTIMATES BY COUNTIES
IN THE EEL RIVER WATERSHED

Year	Humboldt	Mendocino	Trinity	Lake	Total 17/
1880	5,560 18/	2,260	180	Not available	8,000
1900	10,195 18/	3,320	240	Not available	13,755
1920	14,585 18/	5,190	380	Not available	20,155
1940	18,815 18/	5,340	250	Not available	24,405
1960	28,400	11,450	430	50	40,330
1970	35,000	15,300	550	150	51,000
1980	41,000	18,000	700	300	60,000
1990	52,000	22,000	900	450	75,350
2000	63,000	25,000	1,100	600	89,700
2010	78,000	30,000	1,300	800	110,100
2020	92,000	38,000	1,500	1,000	132,500

Source: Cole, D. K., "Future Economic Development in the Eel River Hydrographic Unit." Memorandum Report, State of California, Department of Water Resources, Northern Branch. 50 pp. (typed) 1962.

17/ No known population in Glenn County portion.

18/ Estimate adjusted according to Humboldt County census data.

TABLE 3

ESTIMATE OF EMPLOYMENT IN THE EEL RIVER WATERSHED

Industry	1960	1990
Basic Industries		
Timber	5,000	6,500
Agriculture	600	1,500
Manufacturing	300	900
Commercial fisheries	200	350
Minerals	100	150
Subtotal	6,200	9,400
Service Industries		
Recreation	1,500	4,900
Wholesale-retail trade	1,800	2,300
Construction	600	1,800
Transportation	500	800
Communications, utilities, and miscellaneous	1,200	2,500
Subtotal	5,600	12,300
TOTAL	11,800	21,700

Source: Cole, D. K. "Future Economic Development in the Eel River Hydrographic Unit." Memorandum Report, State of California, Department of Water Resources, Northern Branch. 50 pp. (typed) 1962.

TABLE 4

ESTIMATED LAND OWNERSHIP BY TYPE OF OWNERSHIP IN THE EEL RIVER WATERSHED

Type	Acres	Percent of total land area
Public Lands		
National Forests[19]	425,000	18.0
Public Domain	90,000	3.8
Indian Lands	20,000	0.8
State Parks	25,000	1.1
Miscellaneous State and County	10,000	0.4
Subtotal	570,000	24.1
Private Lands	1,788,000	75.9
TOTAL	2,358,000	100.0

Source: Department of Water Resources computations based on data furnished by the U. S. Forest Service, Indian Service, Pacific Southwest Field Committee[20] and State of California, Division of Beaches and Parks.

19/ National Forest boundaries contain about 500,000 acres, of which 75,000 are estimated to be private lands.

20/ Pacific Southwest Field Committee. "Natural Resources of Northwestern California, Preliminary Report Appendix, Land Use, Land Classification, Timber Resources." (Prepared by the Department of the Interior, Bureau of Reclamation.) 127 pp. 1956.

TABLE 5

ESTIMATED LAND OWNERSHIP BY COUNTIES
AND TYPE OF OWNERSHIP IN THE
EEL RIVER WATERSHED

County	Public (Acres)	Private (Acres)	Total (Acres)	Percent of all lands
Mendocino	159,040	872,610	1,031,650	43.7
Humboldt	44,010	719,160	763,170	32.4
Trinity	180,040	138,920	318,960	13.5
Lake	150,540	40,130	190,670	8.1
Glenn	36,370	17,180	53,550	2.3
Total	592,000	1,766,000	2,358,000	100.0
Percent	24.1	75.9	100.0	

Source: Adjusted unpublished records from U. S. Department of Agriculture, Soil Conservation Service; Forest Service planimetric map, Mendocino National Forest; Department of Water Resources data.

Possible Water Projects in the Eel River Basin

The Department of Water Resources, in its reconnaissance investigation of the North Coastal area, has made preliminary studies of numerous potential reservoirs within the Eel River Basin. Similar studies have been conducted by the U. S. Bureau of Reclamation and the Corps of Engineers. Under various proposals, these storage projects may be operated as independent units or as units in a complex system interconnected by tunnels, canals, and pumping plants. In any plan of development, the projects would be operated to satisfy local requirements for water supply, flood control, recreation, and fisheries preservation. The water remaining after satisfying these local demands then would be exported from the basin to help meet the demands in other areas of the State.

Although the department's investigation encompasses the entire North Coastal area, the main study effort was directed toward analysis of plans for major developments on the Middle Fork and the Upper Main Eel Rivers. The Upper Eel River Development was selected as the initial development in the North Coastal area in March 1964 and advance planning studies were initiated on it in July 1964. The following is a brief description of the major storage features shown on Plate 6, "Possible Water Projects in Eel River Watershed."

English Ridge Reservoir, on the upper main stem of the Eel River, about 20 miles northeast of Willits, would impound about 1,800,000 acre-feet of water. Diversions would be made from the reservoir to water service areas in the Russian River Basin, the Clear Lake area, and within the Eel River Basin.

Spencer Reservoir, on the Middle Fork Eel River, near Covelo, would be formed by Franciscan Dam on Short Creek and by a dam on the River at Spencer Ranch. The 850,000 acre-foot reservoir would provide water service for Round Valley, for downstream uses, including fisheries, and for export to the Sacramento Valley.

Dos Rios Reservoir, on the Middle Fork Eel River, about 2 miles upstream from Dos Rios, would impound about 560,000 acre-feet. Export water developed by this reservoir and/or Spencer Reservoir could be routed via a gravity flow tunnel to the Glenn Reservoir Complex or via pumping to English Ridge Reservoir.

Larabee Valley Reservoir, on the South Fork Van Duzen River would be created by a dam at the foot of Larabee Valley. A tunnel would link this 274,000 acre-foot reservoir to Eaton Reservoir on the Van Duzen River. Water developed in the 400,000 acre-foot Eaton Reservoir, together with flows from Larabee Valley Reservoir, would be routed by tunnel to the Mad River for eventual transfer to the Trinity and Sacramento River Basins.

Branscomb Reservoir would be formed by a dam on the South Fork Eel River below the community of Branscomb. The 30,000 acre-foot reservoir would be used primarily for recreation and for fisheries enhancement. Branscomb would provide no water for export outside the Eel River Basin.

As the most probable major projects are from 10 to 15 years from construction, there should be ample opportunity to evaluate any effects of land use in the tributary areas on their design, operation, and utility.

A more thorough description and analysis of these potential water projects is presented in considerable detail in the digest volume

of Bulletin No. 136 and in a supporting office report, "Alternative Plans for Development." Possible long-range future developments on the Lower Eel River, namely, Bell Springs and Sequoia Reservoirs, are included in those portions of the report.

4. The North Coastal Prairie is a "discontinuous grassland that has developed under much cooler temperatures and higher rainfall than the Central Valley prairie . . . Typically it occurs on tops and upper slopes of ridges . . . . the soils underlying are true grassland soils, closely related to . . . . the great soil group known as 'Prairie Soils'." (Burcham, 1957). A prairie on Laughlin soil near Garberville, Humboldt County.

CHAPTER III. WATERSHED MANAGEMENT PROBLEMS OF THE EEL RIVER BASIN

Given the native combination of geology, soils, climate, topography, and vegetation, and superimposing conditions of use, a number of problems in land management as related to the soil and water resources arise. Some, to be sure, are natural occurrences, but many are the result of man's activity in the area. There is a continual competition for the natural resources of a watershed, and any single group of individuals should not have unceasing priority over the other interests. Some workers would dispute the point that natural occurrences constitute problems, maintaining that such events fall into the "Act-of-God" category and are an everyday fact of life, a part of the natural landscape to be taken in stride and allowance provided for in planning. However, cognizance must be taken of the many resource users in or contiguous to an area, and their individual needs and desires assessed both from an economic and a social standpoint.

Watershed management problems are discussed separately under problem topics, and not by subwatershed units. Some problems tend to congregate in certain drainages, while others are quite widespread. At the conclusion of this chapter, two case histories of specific problem areas are discussed. These illustrate the nature of watershed management and demonstrate how the misuse of the many resources can result in qualified catastrophes.

Soil Management Problems

Sheet Erosion. This process is one of the most elementary forms of erosion. In it, soil particles are detached from a main body of soil and carried away by moving water. As implied, the water movement is "in sheets" or over the surface of the soil in essentially laminar flow. Like many natural processes, it is simple in appearance but complex in nature,

depending upon a great number of natural factors, one of the most important being the restrictions to flow on the soil surface.

These restrictions to flow are usually the vegetal covering of the soil, the native grass mulch, tree leaves, twigs, and needles. The soil surface is also protected from the kinetic energy of falling raindrops by the cover itself, the grasses, brush, and trees. The removal of the cover or the surface soil armour is an invitation to sheet erosion with the advent of sufficient rain.

Although most of the soils in the Eel River Basin have a relatively high resistance to surface erosion, a history of grazing has produced scattered areas where sheet erosion has taken place. It is found most frequently in the central belt of grass, woodland-grass, and woodland, but is by no means restricted to these bounds. Certain portions of Etsel Ridge offer outstanding examples of overused sites -- in this case, by sheep -- and are eroded to a nonsoil or erosion pavement condition.

Sheet erosion can gradually blend into rills with the natural concentration of moving water, and eventually into gully erosion.

Gully Erosion. With the concentration of overland flow into ephemeral channels, gullies are sometimes formed. These are storm channels formed in the soil mantle which are more than temporary in nature, not easily obliterated or healed by the usual forces of nature. They generally result from a surplus of water concentrated on an insufficiently protected slope. By any one of a number of means, the grade of the established channel is upset. As water is crowded into the newly

formed channel, excessive velocities occur and further erosion and soil transport takes place, aided by turbulence prompted by the higher velocities. Gully formation usually proceeds upstream on tributary drainages by waterfall cutting, and in the end a complex gully network is formed, eventually again achieving natural equilibrium with its channel capacities, roughness, grade, and flows. This process is actually a complete geomorphic cycle of channel cutting on a small scale.

Examples of gully erosion in the Eel River watershed are numerous and widespread. A number of severe examples can be seen along Mail Ridge Road in Humboldt County. Others can be seen on Etsel Ridge, along the Dos Rios-Covelo Road, and in many glade areas. Like sheet erosion, gully erosion is not restricted to any one specific area, although it does appear to be more prominent on grasslands of the central belt.

The causes of gully erosion can be numerous. Gully formation has been blamed on overgrazing, logging, cultivation, recreation, travel, climatic change, road construction, and other causes. Examples cited herein are thought to be primarily the results of poor drainage planning on roads, and more specifically, by the injudicious placement of culverts; concentrating unusually large flows in channels which are unable to accommodate them. Erosion from improperly placed drainage structures can be found on highways of every echelon in the Eel River Basin.

Bank Cutting. While gully flow and sheet erosion is an ephemeral occurrence, erosion can occur along permanent and intermittent streams also. In this situation, erosion results from the cutting action

of water against the banks of the stream, causing instability of the slopes, and the consequent movement of soil and rocks into the channel itself. In some instances this appears to be a natural occurrence reflecting the geomorphic youth of the area, but many times it is man-aggravated. Some human activities deposit debris or fill in the channel of a live stream. Such deposition reduces the cross sectional area of flow, resulting in an increased velocity and turbulence, in some cases forcing the flow against the opposite bank. These two factors can cause bank cutting and soil movement.

Examples of this phenomenon, to a degree, can be found at some point along almost any permanent stream in the study area. Perhaps the most accessible and noteworthy example of bank erosion occurs along Long Valley Creek at its junction with Outlet Creek, along Highway U. S. 101 at Longvale, shown in Photo 5.

Landslides. Landslides are the Eel River's most notorious item from a soils management point of view. They have been geologically important in forming the landscape, and are presently a somewhat limiting factor in the development of the area. The effect of the landslides in limiting access through railroads and highways has been quite pronounced. Their effect on soil loss and sediment production is not, however, well known, although it is suspected of being quite instrumental in the latter respect.

Although both are termed landslides, earthflows and slumps make up the broad category, as discussed in Chapter I. Earthflows occur

5. Bank cutting on Long Valley Creek near the junction with Outlet Creek at Longvale, Mendocino County.

naturally on soils derived from finer grained sedimentary and metamorphic rocks, being most common on the Yorkville and Laughlin soil series in grasslands, and the Atwell series on lower slopes in timber. Lack of adequate subsurface drainage results in lubricated subsurface soil zones below the surface soil but above solid bedrock; and large areas of soil, under the influence of gravity, "creep" downhill slowly much in the fashion of a continental glacier. The flow makes "islands" or knobs of the more resistant rock outcrops, resulting in an undulating landscape, as is shown in Photo 6. Large areas of the Eel River Basin are of this nature, and quite evident as such. An outstanding example is found in the area adjacent to Mendocino Pass. Typically they are almost entirely in grass, contain soils in which the smaller particle size classes dominate, possess a distinctive rolling hummock and knob appearance, contain small wet-weather ponds, and show distinct evidences of moisture, sometimes by seeps and springs. These flows can commonly be found along ridge tops and at higher elevations in the central and eastern areas of the Eel River Basin.

Where volumes of earthflow accumulate on steeper slopes, sufficient depth is attained to trigger standard rotational-type landslides[1/]. Often this occurs at the lower end of the slope, close or adjacent to a stream channel. If the streamflow is deflected against the opposite bank, cutting can cause a loss of stability on that side, resulting in additional sliding. In any case, the evacuation

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1/ These occur due to failure under shear of subsurface soil layers along an approximately circular plane.

6. Grasslands and landslide topography. Mail Ridge Road, Humboldt County.

of material at the bottom of the flow (or slump) allows movement downhill of the residual uphill soil. Thus progresses the cycle of earthflow-slump-washing-etc. An entire mountainside can be so affected.

Because slides are sensitive to moisture, it would be difficult for a dry area to slide. Management of these lands should, therefore, not detain water or encourage infiltration on potential slides. It might then be speculated that gullying a slide might reduce its ability to hold moisture and lessen chances of movement. On the other hand, terraces caused by grazing could hold runoff water back, curtailing surface runoff and gullying, but fostering infiltration. Woody vegetation, which uses water, may decrease soil moisture, but add substantially to the loading of the slide and stress on the shear zone.

The amount of sediment which is placed in streams, naturally and by man's aggravation, from slides is largely unknown. Such slides are found on the main stem of the Eel River from Eel Rock to the vicinity of Hearst along the lower reaches of the Black Butte River, on the Middle Fork Eel River above the Covelo Ranger Station, and somewhat locally elsewhere.

The management of these areas will be important to the development of water projects in the Eel River Basin, as their lack of stability often causes undesirable effects.

Vegetative Management Problems

Timber Harvesting Practices. Timber harvesting is an industrial process whereby standing trees are felled, trimmed, bucked, yarded, and transported out of an area. It is a harvest of commercial forest crops, and can represent the reward for years of care, fire prevention, and husbandry. It can represent the repayment, in many cases, of a sizable investment for

the landowner and timber operator. Timber harvesting is a necessary part of timber forestry, and an absolutely irreplaceable item in an economy based on forest products.

However, it has been the subject of a great deal of criticism because of damages attributed to associated resources. It has frequently been asserted that timber harvesting is the triggering action which has caused accelerated erosion, fisheries resource reduction, site depletion, increases of flood potential and fire hazard, and changes of climate and streamflow regimen.

The outstanding immediate effects of timber harvesting are: (1) the temporary removal of the vegetative cover; (2) the disturbance resulting from dragging harvested logs across the soil; (3) the effects resulting from the construction of logging roads. This last factor is, in most cases, the most important.

The temporary removal of the forest vegetation is necessary by the definition of timber harvesting. If the crop is to be harvested, the tree stems must be removed from the forest to be processed elsewhere. In the removal, logs are dragged by a variety of means both uphill and down to a collecting location where they are loaded on trucks or flat cars and shipped elsewhere. Often this leads to a great deal of disturbance in the surface layers of soil, gouging minature channels and injuring smaller trees and plants. Thus, at this stage, a degree of the protective cover has been removed, exposing freshly turned soil and potential raw runoff channels to the elements. Ensuing rains promote erosion, the magnitude depending upon the severity of the disturbance. Using present methods, and with present values of site and timber, it is almost impossible to avoid some

degree of the damage described above. The damage can and should, however, be kept to a conscientious minimum. On the steeper slopes, especially over 50 percent, where conditions and economics allow it, high lead logging may well be the best logging method to minimize erosion. In high lead logging, roads tend to be fewer and generally located more toward the ridge tops and up out of the stream bottoms. The problems of skid trails converging to landings and the consequent concentration or funneling of water is avoided.

The necessary roads which must accompany timber harvesting are usually the most profound, although unappreciated, by-products of the operation. Roads in general are covered in more detail elsewhere in this report, but their connection with logging and erosion should be acknowledged. In connection with logging, they tend to be of only temporary service, designed for the life of the operation. They are usually of a natural, or soil base, formed conveniently with bulldozers, and for skid trails, abandoned when their utility is no longer desired. Cuts in slopes deposit raw soil on the downhill fill and undermine soil on the uphill cut. Use of the road promotes compaction and therefore reduces infiltration. This and the channelized nature of the roadbed encourages the collection of surplus waters and subsequent flow down road cuts. Channel erosion in the roadway results, and where finally drained, erosion of the fills. Stream crossings, if culverted, often contain high outfalls, and erosion at that point results from the expenditure of the kinetic energy of falling water on unprotected fill. Under extreme conditions, all of the above damages can occur at a single site, although it is more common to find individual examples in scattered operations.

In the Eel River Basin, damage due to timber harvesting is naturally greatest where most of this activity occurs; i.e., in the redwood

belt. Adding to the complex problem is the occurrence of large timber, fragile soils, steep slopes, heavy rainfall, and the economic demand for harvest. In the fir-pine areas, damage is generally not as severe because of reductions in these factors, and because of the more spotty occurrence of the timber and strict timber harvesting controls demanded by the U. S. Forest Service on National Forest lands.

The detrimental consequences of timber harvesting are both on-site and downstream. The on-site effects are subtle and include the expenses of maintaining an eroding roadway, the reduction of timber growth potential, and the increase of fire hazard. The downstream effects include all the flood, debris, and erosion items mentioned under the section on Sediment, but by far the most publicity has been centered on the effects of logging on the fisheries resource. Evans[2/] outlined three means by which this is affected by current West Coast logging practices. These are:

1. Covering up and smothering fish eggs and food organisms with soil.

2. Alteration of vegetation causing variations in flow regimes; especially by reducing summer flows and increasing summer water temperatures.

3. Decomposition of slash in streams, causing oxygen deficiencies. Other effects include the blocking of streams, with logging debris, the crushing of eggs in stream crossings, the compaction of spawning gravels by logging equipment, and the

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2/ Evans, W. A., "The Effect of Current West Coast Logging Upon Fishery Resources." Proceedings of the Society of American Foresters. pp. 106-8. 1959.

encouragement of erosion and sediment production through soil disturbance and exposure. Many of these items, and timber harvesting problems in general, are of comparatively recent origin, being the product of a mechanized society, and advancing with the advent of large logging machinery, large scale operations, sudden and complete denudations, and high speed traffic.

That reduction of fisheries in the Eel River Basin has occurred is a matter of record. Calhoun[3/] described this as follows in discussing the South Fork Eel River:

> "The present (1962) condition of much of this watershed is deplorable. And the fish have suffered badly, especially salmon. Runs of king (salmon), counted over Benbow Dam, dropped from a 14-year average of 11,831 adults prior to 1952, to a nine-year average of 3,735 since then. The decline coincides almost exactly with the great logging boom in this area after the war. Silvers have followed the same pattern. Steelhead seem to be more resistant and they have suffered less."

Statistical analysis of these data shows highly significant declines of king salmon, silver salmon, and steelhead, the run being reduced to about half of its former size. A mass curve demonstrating this decline is shown on Figure 1. The scientific method, however, demands that a number of explanatory hypotheses be offered to explain a phenomenon, and then suffer systematic disproval. One might speculate that the decline of the anadromous fish run at Benbow was caused by diseases, increases in sport or commercial fishing, adjustments in

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3/ Calhoun, Alexander. "Logging Damage to Streams." Paper presented to California Fish and Game Commission. November 9, 1962.

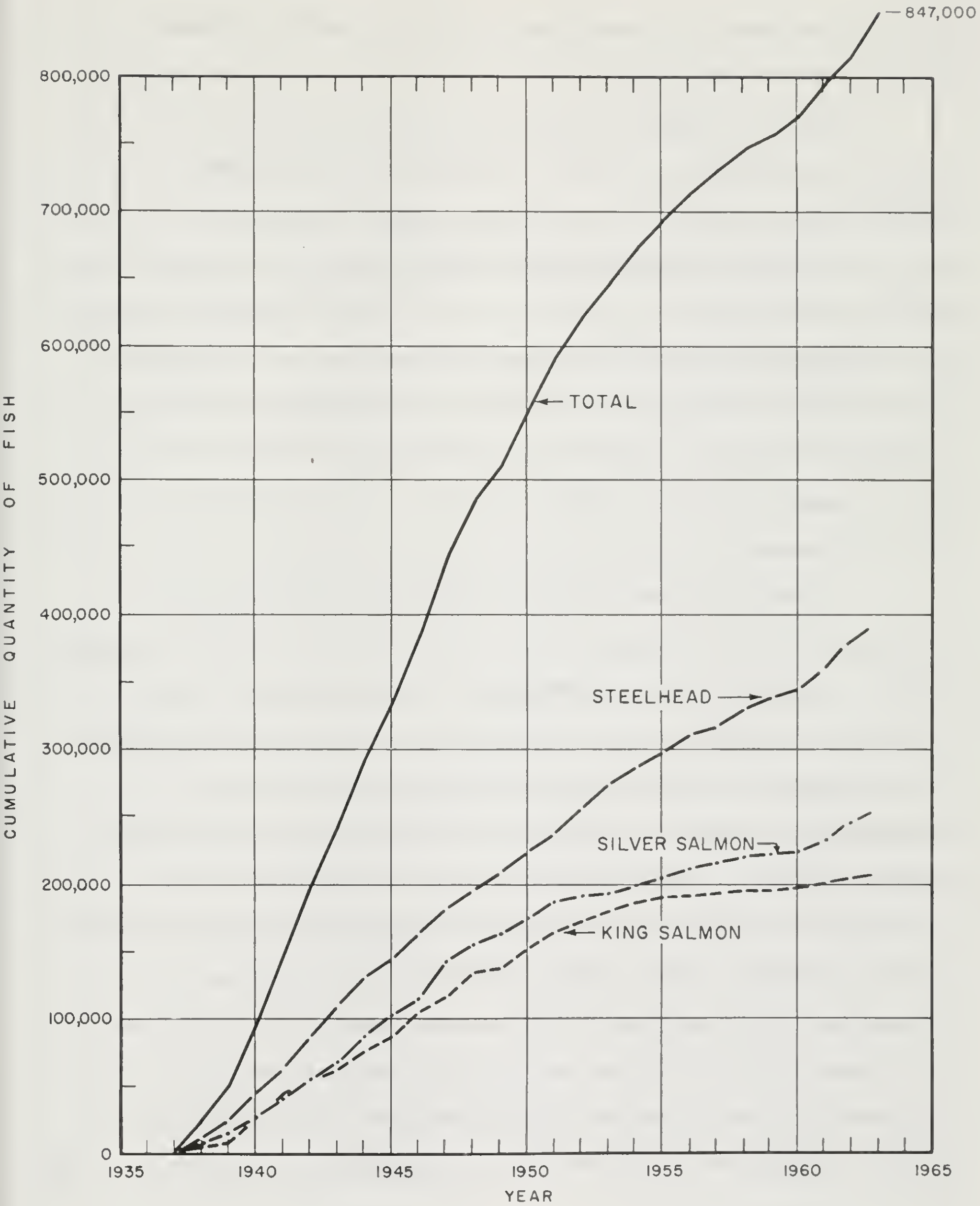

Figure I. MASS CURVES OF FISH COUNTS AT BENBOW BY SPECIES

numbers of predators, or perhaps because of the undesirable effects of timber harvesting operations.

The act of timber harvesting need not be unnecessarily destructive, nor need all consequences thereof be undesirable. Often the wildlife habitat is improved by it, and increases of summer streamflow have been known to occur after logging in various areas. While the topographic and climatic characteristics of the Eel River Basin make it impossible to avoid some soil damage by present timber harvesting methods, this injury can be kept to a minimum. However, as a general rule, improvement of logging techniques to make them compatible with other land use consumes profits, and a commercial enterprise, which exists because of the profit incentive, shuns this hygiene.

Timber harvesting methods are a matter of economics for all parties concerned. The logger and the landowner seek to accomplish a given specific task with a minimum of immediate financial expense. Those concerned with the overall resource development of an area wish to accomplish the maximum benefit to all resources, including the soil, water, and fisheries. The fishing enthusiast would no doubt like timber harvesting ceased completely in areas tributary to angling streams. Thus, the justification for timber harvesting cannot be based only upon a consideration of the net benefits derived from any one resource, but also upon the damages (or benefits) which will accrue to associated natural resources as a result of the use of that resource. This theory is not always practiced in private enterprise, which normally has little economic interest in downstream activities, but is accepted as fact by most

concerned federal and state agencies. It is made vividly clear in the case of timber harvest.

This conflict is one of the most direct examples of the use of one resource damaging the use of another. Both uses are valid, and certainly neither should be discontinued because of the other. There does appear to be a need for all factions to recognize the validity of the other uses of land and water.

<u>Grazing</u>. The use of wild lands for grazing takes place over large areas in the Eel River Basin. The earlier agricultural enterprises in the area were small family farms and larger ranches, and today almost all the nonurban and wild lands are grazed by domestic stock to some extent with the exception of state parks and certain commercial forests.

The <u>north coastal prairie</u> (see previous discussion under <u>Vegetation</u>) constitutes some of the best natural grassland range in the State. In its original condition, the unit grazing capacity of the entire California prairie was in the neighborhood of 2 acres per animal-unit month. A history of uncontemplated use has altered this to about 3.8 acres per animal-unit month, which is still superior to oak-woodland (4.5), coniferous woodland (7.8) and chaparral (36.0). This large difference in grazing capacities may explain some landowners' devotion to the use of fire (or any other means) to convert brushlands to grass. While only a small percentage of the grazing lands are pure grasslands, larger amounts are woodland and woodland-grass, comprising together some 670,000 acres, or 28 percent of the total land area. The grazing capacities of different kinds of ranges are shown in Table 6.

TABLE 6

PRISTINE AND PRESENT GRAZING CAPACITIES
OF RANGE LANDS IN THE EEL RIVER WATERSHED

(All figures in acres per animal-unit month)

Kind of range	Pristine	Present
California prairie[4/]	2.0	3.8[5/]
Oak-woodland	2.2	4.5
Coniferous woodland	3.2	7.8
Coniferous forest	18.0	30.0
Chaparral	15.0	36.0

Source: Burcham, L. T. "California Range Land." State of California, Division of Forestry, Department of Natural Resources. 261 pp. 1957.

Ranches are scattered throughout the interior of the Eel River Basin, with prominent concentrations in the central belt of grass and woodland. There is usually very little level land except on ridge tops, and most ranges are on steep slopes. Both cattle and sheep are presently grazed, but there have been goats and swine as well, the latter two having been especially destructive. Much of the rangeland, especially that used by sheep, is grazed throughout the year.

Scattered examples of unquestionable soil damage by grazing animals are present, usually in somewhat inaccessible locations and already barren situations. Most prominent, especially from an aerial view, are erosion rivulets on grassed hillsides. It would be difficult to attribute

4/ Includes north coastal prairie.
5/ Termed grassland in source.

these to anything except grazing activities, as this is essentially the only use these areas receive. Typically, these rills are small and locally numerous, occurring on landslide topography on clayey soils, the blue underlayers standing out in contrast to the plainer adjacent horizons. Areas on some higher ridge tops of the central and eastern extremes show evidence of soil loss from historic overgrazing by sheep, followed up with erosion by water and wind. Sheep trails on hillside ranges can be seen throughout the same area, sometimes being so dense as to nearly cover the entire horizontal range area. These trails undoubtedly compact the soil, cause channelization of flow, and reduce infiltration, but signs of damage which can reasonably be attributed to this situation (besides the trails per se) are not numerous. On Yorkville soils, it is conceivable that the removal of grasses as a water user causes some acceleration of sliding. Also, it is possible that the presence of sheep trails contribute to the collection and impoundment of water on potential slide areas, thereby fostering infiltration into the slide zone.

Thus, although grazing uses a larger area of land than any other activity discussed, the magnitude of its net effect is not known to any real degree of accuracy. Even though the livestock industries throughout the nation are tending towards feedlots, concentration of operations, and larger and more efficient efforts, very little change is expected in the Eel River Basin because of the existing favorable conditions. The effect of range use upon watershed management therefore can only be safely assessed as minor, as the total effect is most difficult to determine. There is no sound reason why grazing under good range management practices should be incompatible with watershed management; especially if there is a continuing educational effort to keep ranchers informed of current developments in the field.

Fire. As with other topics discussed in this report, the use and occurrence of fire as it may affect the general field of watershed management, is the subject of much controversy. Although of more importance in selected areas outside of the Eel River Basin, it is of sufficient interest to merit discussion here.

The first explorers in Central and Northern California found the native Indians using fire to a limited extent to rout game and enhance travel in dense forest and brush stands.[6/, 7/] The extent to which it was used cannot be accurately determined, although all extremes are claimed, and its effect upon the native vegetation has been similarly speculated upon. The first American settlers and miners used fire annually to clear the range, to encourage grasses and tender brush shoots for the consumption of introduced stock, and to expose rock strata of covering vegetation. Very little control was applied to these fires, and they often spread indiscriminately to adjacent lands and did unnecessary damage, requiring winter rains to extinguish them. Besides intentionally set brush fires, a small number of fires occur annually in the Eel River Basin which originate naturally from lightning, although in some years they have been locally numerous.

From a hydrologic sense, fire can be considered as a factor which alters the first stage of the hydrologic cycle. The burning of wild lands affects both the soil and the vegetative cover in direct and indirect manners. Thus, those features of the runoff process which are affected by the soil and vegetation are correspondingly influenced. These features are interception, stemflow, infiltration, detention and retention storage, and

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6/ Sampson, A. W. "Plant Succession on Burned Chaparral Lands in Northern California." California Agricultural Experiment Station. Bulletin No. 685. 144 pp. 1944.

7/ Burcham, L. T. "Planned Burning as a Management Practice for California Wild Lands." Proceedings of the Society of American Foresters. pp. 180-5. 1959.

evapotranspiration. The obvious effects include the consumption through fire of the organic litter and the covering vegetation itself, the destruction of seed sources, and chemical and physical alterations of the soil mantle.

The question of range burning arises and becomes especially acute on brush lands, where resident ranchers must derive income from grazing these lands. Fresh chamise sprouts possess a succulence which sheep and deer desire, and as a result chamise lands are frequently burned for the benefit of sheep. Attempts are often made to convert brush or timberlands to grazing grasslands by using fire. These attempts can be successful in some locations if properly applied and followed up, but can easily be only a minor setback in plant succession, with the end result that a need for an additional burn soon arises. As all soils are not capable of maintaining a permanent grass cover if converted, mistakes in site selection occur and brush is often the end result. This sometimes is the case on marginal timberland where an attempted conversion followed logging. In this respect, the existing soil-vegetation maps and surveys can be used to advantage.

The net hydrologic effect of burning brushlands in California is a much researched project. With full knowledge of then-present conflicts of opinion, Adams, Ewing, and Huberty[8/] conducted a scholarly review of past research and literature on the subject, and concluded that "burning can be neither supported nor condemned for all conditions and situations in the California brush and woodland-grass ranges or watersheds." This was followed by denials that range burning in Northern California was detrimental to water conservation. Other researchers, equally highly respected, found

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8/ Adams, Frank; Ewing, Paul A.; and Huberty, Martin R. "Hydrologic Aspects of Burning Brush and Woodland-Grass Ranges in California." State of California, Department of Natural Resources. 84 pp. 1947.

definite erosion and runoff effects from burning brush cover in different locations in Northern California. Almost all have agreed that additional clarification through more research was needed. The Eel River Basin contains chaparral lands to the extent of about 175,000 acres and grass and woodland-grass of about 575,000 additional acres. Together with the oak-woodland, they comprise close to one-third of the area of the entire watershed, and a past history of fire has no doubt been instrumental in forming present conditions.

Uncontrolled fire can have the natural direct effect of consuming standing timber which may constitute an economic loss of important proportions. According to Fritz[9/], fire has done great damage to standing redwoods, even though in years past, a popular conception has been that fire helps redwoods. Although the classical western United States forest fire does occur in the Eel River Basin, crown fires reminiscent of the infamous Southern California infernos are not the usual case.

Whatever the benefits or damages from burning are, it is presently used as a tool of land management in the Eel River Basin. Burning permits for private lands are issued during the period of the year April 1 to December 1 (in accordance with Section 4153 of the Public Resources Code, as amended 1963) by the California Division of Forestry, and burners must meet requirements of adequate protection against unplanned and uncontrolled occurrences. Grasslands and brushlands are frequently burned to encourage fresh, tender, winter growth, and even some timberlands are thus treated. Present responsibility for the control of fires on National Forests rests with the U. S. Forest Service, and for certain state and private lands with the California Division of Forestry.

9/ Fritz, E. "The Role of Fire in the Redwood Region." California Ag. Exp. Sta. Circ. 323, pp. 1-23. 1932.

The question of the use of fire for land treatment remains a moot point. It is tolerated by managing agencies in deference to local opinions and desires. While the safest approach would be to reduce burning to prudent limits, it probably does not have a valid place with proper application in the Eel River Basin.

Phreatophytes. In certain parts of the arid west, the problem of excessive water consumption by riparian vegetation of questionable economic value has received considerable attention. Those forms of vegetation which habitually obtain their water supply from the zone of saturation and, under proper conditions consume it in significant quantities, are termed phreatophytes or "well-plants." Although the distinction between phreatophytes and other plant groups is not entirely defined, in the arid regions the phreatophytes form a fairly distinct class, and certain species occupy this niche more readily than others. Typical phreatophytes in the southwest are willows, cottonwoods, alder, mesquite, and salt cedar. In some sections along the Salt River in Arizona, dense stands of riparian salt cedar transpire about 7 acre-feet of water per acre annually, a substantial amount in a water-conscious area[10/].

Translating this to the Eel River requires a re-examination of the problem. The most important fact in this respect is that water is a surplus commodity in the Eel River Basin in the winter and spring months. Present riparian vegetation undoubtedly consumes a portion of the summer streamflow, but its amount is unknown. However, there is no reason to suspect that it approaches the magnitude of the Arizona data cited above. The wisdom of

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10/ Koogler, John G. "Phreatophyte Control on Irrigation Projects in New Mexico." Transactions of the American Geophysical Union, 33:74-7. 1952.

denouncing all riparian vegetation in the Eel River Basin as phreatophytes should be criticized, but some attention should be focused on the possible future spread of undesirable water-consuming plants.

The most notorious phreatophyte in the Southwestern United States is salt cedar, also called tamarisk (*Tamarix* spp.). It is an introduced plant to North America, its origin being the Middle East, but it has become well naturalized since introduction, and has invaded much of Arizona, New Mexico, and Texas. Its seeds spread by water, germinate on bare sandy soils, and are quite hardy and vigorous in youth. Tamarisk can form inpenetrable jungles in river bottoms and lake deltas, excluding human use of land, although trapping sediment from flood waves. It is typically found where significant amounts of water flow through an arid area, and it is not hampered by moderately poor quality water.

If the resource manager is concerned with the invasion of undesirable vegetation into his domain, the occurrence of these invaders must be considered. Tamarisk has been located in the channel of Cache Creek in Lake and Yolo Counties, perhaps close enough to the Eel River Basin to anticipate its appearance at some future date. Should it arrive, there does not appear to be cause for undue alarm, as natural conditions of seedbed, radiation, growing season, etc., are quite different than those found in the arid stretches of the Salt River.

Nevertheless, little data are currently available on this matter, and the spread of this plant should be observed with more than passing interest. Future activities in the Eel River Basin may alter the environment of some areas sufficiently, as to make them hospitable for salt cedar or other exotic water-consuming vegetation. Certainly with our knowledge

of its past performance, and our lack of knowledge of its spread in northwestern California, it should not be brushed aside and forgotten.

Water Management Problems

The separate treatment of the soils, vegetation, and water problems of the Eel River Basin should not cause the reader to suppose that they are independent of each other. Rather, an attempt is being made to demonstrate the common bonds which exist between one resource and the others.

As outlined in the descriptions of the climate and hydrology of the subject area, the main water problems, per se, are in order of importance: (1) the periodic occurrence of damaging floods, (2) low summer streamflows injurious to both recreation and fisheries, and to other direct human uses. What then, might have been done, or can presently be done, in the field of watershed management to meet the needs posed by these problems?

Floods. The concept of watershed management has been historically prompted by the supposed effects of land use on flood peaks. Some of the earliest proponents were agricultural agencies, claiming that through judicious management of lands under their authority, significant reductions in flood peaks and damages could be achieved. Unfortunately, arguments were largely based on hearsay, appeals to authority, and "arm-chair philosophy" and very little authentic research was undertaken. Over the years, scientific investigations have shown that general rules do not apply to this topic and that each instance must be evaluated on its own. A careful review of acknowledged facts, however, can be helpful in more adequately understanding this facet of watershed management.

Floods take place when the discharge in a reach of stream becomes greater than the capacity of that reach and consequent overflow into the

surrounding area occurs. It usually is the result of heavy and/or prolonged rains, in which the initial natural storage elements of the hydrologic cycle become saturated, and the rate of runoff approaches the rate of rainfall. Important natural factors in flooding are the nature of the precipitation and of the drainage basin upon which it falls.

At the present time man exercises no conscious control over the precipitation which falls on the lands he inhabits. Nor has he any control over the native size, shape, or topography of the receiving watershed. The only factors which are influenced by human activity are the condition of the soil and vegetative mantle which he uses, and to a lesser extent, the channels in which storm waters flow.

In many places in the United States, flood peaks have increased after various kinds of land use -- timber harvesting, grazing, urbanization, burning, etc. In California, the case histories of the fire-floods sequence in the San Gabriel Mountains adjacent to Los Angeles are often cited. Equally impressive examples can be found in the Wasatch Front in Utah, the Boise area in Idaho, etc. Every western state can offer samples. However, it should be noted that in almost all cases, it was not only the flood waters themselves which have been damaging, but the sediment load which accompanied the waters as well. Also, the areas in question have not been the large basins of major river systems.

In that the soil and vegetation can absorb and detain waters, they can aid in the control of runoff, and thus affect the flood potential of a drainage. This can be accomplished through vegetative interception, by the infiltration of waters, and by the temporary storage of water in natural pockets and depressions.

For example, if a given soil and vegetation complex could accommodate an inch of water under a given condition of intensity, it might absorb 100 percent of a one-inch storm. On the other hand, from a storm of 20 inches (representative of the December 1955 storm and flood on the Eel River), the soil would retain only 5 percent of the storm rainfall. That is, any rainfall in excess of the absorptive capacity of the soil will become runoff, regardless of how the land has been used. This reasoning is especially cogent in the case of a fresh storm falling upon previously saturated land. Furthermore, water absorbed into the soil is not all lost to streamflow forever. These waters, too, can enter surface streams through subsurface flow, and become the base flow for surface runoff.

The role of vegetative interception is also limited. For small storms, the percentage of precipitation retained in vegetation can be quite large. With progressively larger storms, however, although the amount of interception continues to increase, the percentage decreases sharply. Thus, for small storms, the vegetation is significant, for large storms it is insignificant.

Will proper land-use practices slow up the overland flow of water to channels, and thus significantly delay runoff and reduce flood peaks? It is not difficult to envision that differences in streamflow regimen can result from extreme variations in land use. However, on small basins the changes will be significant only if the change in time of overland flow is greater than the natural lag of the basin. On larger watersheds, the effect becomes less pronounced, though still present. Because of the natural intricacies of the hydrologic processes involved and the many effects of the storm and the channel upon the flood wave, effects of land management become more difficult to detect as the runoff moves more distant from its point of origin, the land. Furthermore, delaying flood peaks could yield undesirable results. The superimposition of tributary peaks one upon the other would

increase the discharge at a junction. Perhaps under less judicious land management, tributary flows might reach a junction out of phase and thus reduce the otherwise expected peak.

However, all uses of land management to man's benefit in respect to flood problems should not be forsaken. Recalling the high proportion of flood damage from sediment, land management should be aimed at reducing man-caused and sometimes natural erosion. As waters of the flood category are difficult to control with vegetation, all reasonable attempts to control accompanying soil movement should be made.

In the Eel River Basin, there is reason to suspect that much stream-carried sediment is derived from channel adjustments, either from landslides, bank cutting, or channel degradation. A good deal of this erosion is the result of a natural geologic occurrence. Whether it can or, indeed, should be controlled is an unresolved question.

On small drainages, flood potential can be affected by the occurrence of gully erosion. Through an incised network of bare ephemeral channels, the drainage efficiency of an area can be increased, thus negating any effect of vegetation in delaying overland flow. The eroded sediment can contribute to the downstream flood potential by raising river levels, etc., as discussed previously.

In summary, a quotation from Hoyt and Langbein[11/] seems most appropriate:

> "... it is seen that the major effect of improved land practices is on the regimen of (1) small streams and (2) small floods. Great floods seem to overpower all effects of vegetation and bear more marks of the storm than of the land surface."

11/ Hoyt, William G., and Langbein, Walter B. "Floods." Princeton University Press, Princeton, New Jersey. 469 pp. 1955.

Water Conservation. There is, in the Eel River system, a relatively minor but very real need for the conservation of winter flood waters for release during the summer periods of low flows. These improved summer flows would be utilized for the improvement of recreation and fisheries values, and for conventional agricultural and domestic uses. The most recent departmental studies have indicated that the probable water needs in the Eel River Basin for the year 2020 will approximate 300,000 acre-feet annually. About a third of these needs were distributed in the upland valleys and two-thirds were in the vicinity of the Eel River Delta.

This future need would presumably be satisfied by storage plans as proposed by federal and/or state agencies, exporting some surplus stored waters and controlling floods at the same time. In a system of large dams and reservoirs, some small but urgent local demands for agricultural, fisheries, or domestic water could fail to be served because of their inopportune locations. Smaller projects, which might serve as alternates in local service are difficult to locate, plan, operate, and finance.

Because of the erratic nature of the rainfall and runoff in the Eel River Basin, and because of the relative lack of natural storage or aquifers, the amount of flow in the summer months is largely a function of the amount of water which can be stored in the soil and rock mantle, which is, in turn, partially influenced by the covering vegetation. As the essence of the water supply problem is a lack of summer surface flow in a region of surplus winter flows, what steps in land management might conceivably be taken to alter the natural regimen of streams to increase the total usable yield?

In certain areas and under certain conditions, total water yield as well as summer flows can be increased by the judicious removal of vegetation.

In fact, such has been sometimes noted after fires or logging. Conditions requisite for this treatment are a deep soil mantle, with an original deep-rooted vegetation to be removed, and native geology of such structure that salvaged water will appear on the surface. Water not consumptively used during summer months then seeps out where aquicludes or the water table intersect the ground surface. It must still reach a point of use before a benefit can be asserted, and unless tapped at the ground water outlet (in effect, a spring), there is considerable danger of losing all or part of the salvaged flow as seepage into drier areas.

The California Division of Forestry, in cooperation with the Pacific Southwest Forest and Range Experiment Station of the U. S. Forest Service and the Department of Water Resources, has initiated a watershed study project on Caspar Creek near Ft. Bragg. This study is planned to eventually yield at least some streamflow data as affected by logging in one portion of the drainage. However, the only current <u>long-term</u> established research on this matter in the North Coastal area is at the Hopland Field Station of the University of California, about 35 miles southeast of Willits, in the Russian River drainage. Here, a 200-acre oak-covered watershed, with an intermittent draining stream,underwent treatment. Almost all resident oaks were poisoned in the treatment, and the stream became perennial the following water year. Low sustained summer flows approximated 10 gallons per minute (1/45 of a second-foot). This amount, seemingly low, if utilized at the watershed mouth, could support a small community of about 100 persons or several acres of irrigated crops. Concurrently, the range forage production on the treated watershed was increased considerably. An adjacent drainage, 40 acres in size, was burned to remove vegetation, and similarly gaged. Summer surface flows did not increase at all, due to the fact that early season flows sank into channel bottom sand before reaching the point of measurement. It should be noted that these

experiments were carried out on small drainages, and dealt with what amounted to only a trickle of water.

Could such applications of judicious vegetative removal be made in the Eel River Basin? Even if the question could be answered accurately, it would have little import, as there are no suitable locations without an alternate source of a more conventional nature. Sample locations might be Fort Seward or Alderpoint (on the Eel River), Covelo, Laytonville, or Willits (in alluvial valleys with usable ground water reserves). In short, the prospect is made unnecessary by the small population, with concentrations at existing available sources of water. There could be limited application by ranchers to provide stockwater with a concurrent range improvement program on small drainages. Such programs, if successful, have been demonstrated to be economically feasible.

Another approach, that of influencing summer runoff by the maintenance and encouragement of vegetation is sometimes mentioned. Numerous small streams in the redwood belt, which receive a minimum of about 75 inches of precipitation annually and are heavily covered with vegetation, flow all summer; apparently as a result of storage of water in the soil and rock mantle, which are prompted by high infiltration rates and deep soils in the forest community. Canoe Creek, draining about 10 square miles in Humboldt County and relatively unused, was found flowing at an estimated one second-foot of flow in mid-September 1962. Similarly Elk Creek, near Canoe Creek, draining about 6 square miles was flowing at a similar discharge, as were Panther and Cuneo Creeks, both tributary to Bull Creek. Elder Creek, a virtually untouched tributary to the South Fork Eel River near Branscomb, which drains 6.5 square miles, usually flows the year round. Undoubtedly, other examples exist, requiring only documentation and measurement to substantiate their magnitudes.

The role of vegetation with respect to the redistribution of seasonal flows might then be questioned. Assuming that the presence of forest or brush growth on a drainage will act to detain surface runoff, and thus promote infiltration and storage of water in the soil profile, of what magnitude and importance is it? As a portion of the additional water will be consumed by vegetation during the growing season, the amount of storage which is promoted by the vegetation must exceed the potential summer consumptive use of the vegetation, or be placed at such depth as to be inaccessible. Normal water losses (precipitation minus runoff) in the Eel River Basin vary from 20 to 30 inches[12/]. Therefore, using 2 feet of water as a working figure, the vegetation and soil complex would be required to promote a good deal more than this amount of water to storage, as some water would drain during the wet season.

Complexities enter into this analysis upon further examination. Contemplation encourages further questioning of the present role of vegetation: is it a partial cause of streamflow, or merely a concurrent effect of the rainfall? Examples of late summer flows are found in both essentially virgin and heavily damaged areas -- as is illustrated by comparing Canoe Creek with neighboring Cuneo Creek. Canoe Creek drains portions of Humboldt Redwoods State Park near Weott, while Cuneo Creek is a tributary to Bull Creek, draining highly eroded slopes with very little covering forest.

Thus, because of conflicting examples, no positive statement can be made concerning this speculated effect. It can, however, be observed that these late summer flows do occur in areas receiving heavy precipitation, and some summer fog. More detailed statements can be safely made only upon

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12/ Rantz, S. E. "Surface Water Hydrology of Coastal Basins of Northern California." U. S. Geological Survey, Water Resources Division, Menlo Park, California. (Prepared in cooperation with the California Department of Water Resources.) 97 pp. 1961.

scientific analysis of records of streamflow, precipitation, fog and fog drip, geology, and soil and litter moisture studies.

Sediment. Although not immediately evident to a casual observer, there is a great deal of sediment transported in the Eel River and its tributaries. In part, this is the natural product of geologic erosion and mass wasting. The erosion contribution to this process, covered elsewhere in this report, provides the particles to be transported by water to the various locations where deposit may occur. The three actions -- erosion, transportation, and deposition -- occur time and time again, until the particles eventually precipitate into the ocean.

Typically, movement of fine, suspected sediment in the Eel River system varies directly with the flow. However, variation in suspended sediment discharge changes with the seasons, a more sensitive response with flow occurring in the fall and early winter months than in the late winter and spring months. A curve showing the variations in this response closely resembles the hysteresis curve familiar to students of electrical engineering. This curve is shown in Figure 2. Most of the sediment flow appears to occur during a small percent of the time, thus escaping the eye of most observers. A curve illustrating this phenomenon is shown in Figure 3.

While sediment is composed of common particles of soil and rock which have become waterborne, its role in the water is markedly different than on the soil surface. While on the land it occupies a position near the "source of life," in the stream channels it tends to be "life destroying."

Perhaps the effect of sediment upon the fisheries resource should be noted first. Due to the manner in which the reproduction segment of the life cycle of anadromous fishes takes place, the smaller sediment particles are of major concern. When salmon and steelhead eggs are deposited in stream gravels, oxygen must be transferred from the water to the eggs in

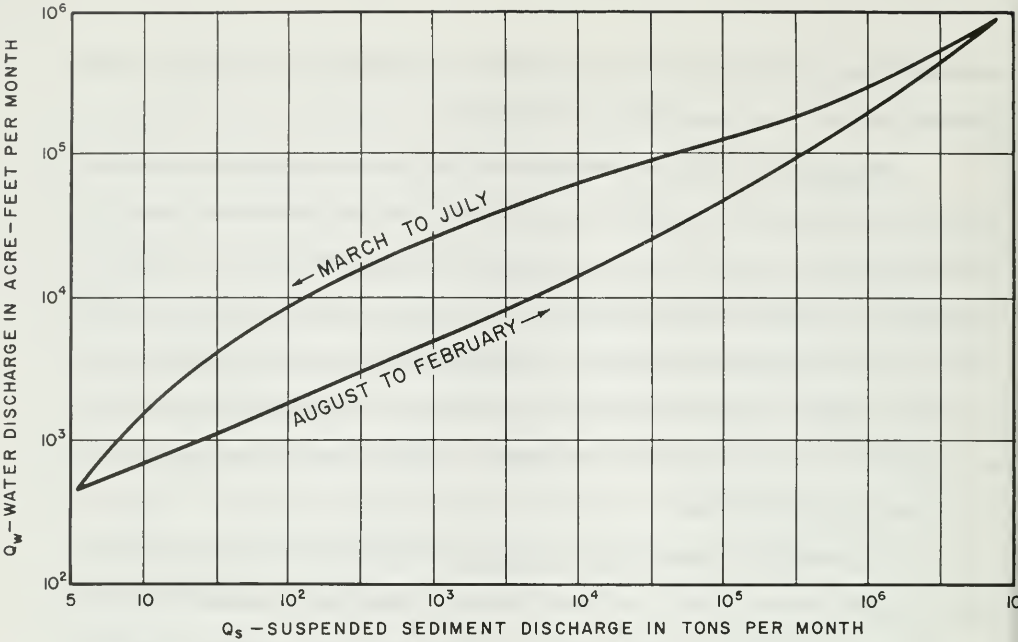

Figure 2. SEDIMENT–WATER DISCHARGE CURVE
MIDDLE FORK EEL RIVER AT DOS RIOS (D.A.:753 SQUARE MILES)

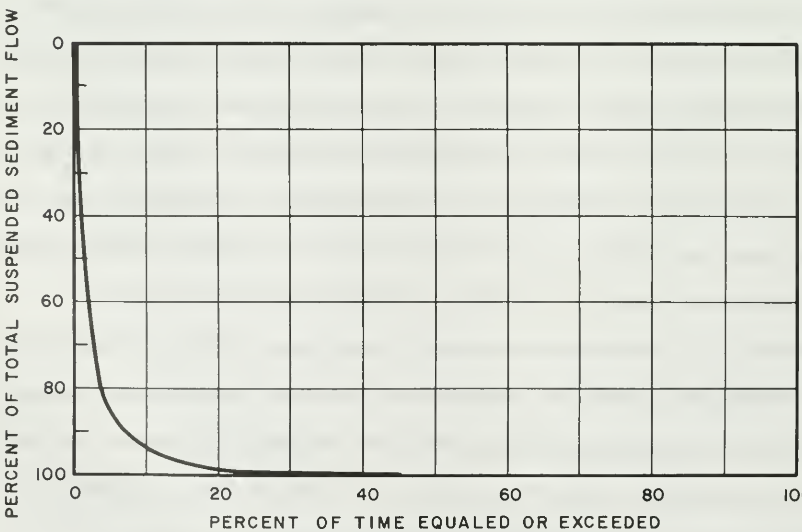

Figure 3. DIMENSIONLESS SUSPENDED SEDIMENT–FLOW DURATION CURVE
EEL RIVER AT SCOTIA (D.A. :3113 SQUARE MILES)

order to maintain life. When finer particles of sediment are allowed to precipitate onto the eggs, the oxygen supply is cut off, and the eggs smother under a blanket of muck. Moreover, deposition of these fine sediments as well as larger size classes reduce the aquatic insect production, which constitutes a major food source for these fish.

The deposition of sediment can have more subtle effects. By the mere presence of their volume in a stream channel, flood stages are raised, and low flows revert from open-channel discharge to seepage through sands, which do not support stream wildlife of any kind.

The function of sediment in the destruction of lake and reservoir storage is well known, and is summarized in the statement that "that history of a lake is the story of its death." From the moment a lake is formed, it begins to accumulate sediment, thus gradually effecting a loss in use potential, it being only a matter of time until the lake becomes a flat of alluvial material.

Presumably then, if the erosion, sediment transport, and sediment deposition rate could be reduced, the life of a downstream reservoir could be increased substantially. This type of reasoning certainly deserves recognition in planning North Coast features of The California Water Plan, where reservoirs can be expected to act as sediment traps in the high sediment yielding parts of the Eel River Basin. In specific terms, elementary calculations[13/] using conservative assumptions yield the results shown in Table 7.

More realistic figures on unit sediment production in the Eel River Basin are shown in Table 8, based on U. S. Geological Survey data and departmental computations.

13/ Brune, G. M. "Trap Efficiency of Reservoirs." Transactions of the American Geophysical Union, 34:3. pp. 407-18. 1953.

TABLE 7

RESERVOIR AND SEDIMENT STORAGE OF PROJECTS IN THE EEL RIVER WATERSHED 14/

Reservoir	Storage (acre-feet)			Sediment Trapped (acre-feet) 15/		Percent of Dead Storage	
	Active	Dead	Total	50 yr.	100 yr.	50 yr.	100 yr.
Spencer-Franciscan	448,000	82,000	530,000	22,000	44,000	27	54
Jarbow	250,000	35,000	285,000	33,750	67,500	96	193
Larabee Valley	254,000	20,000	274,000	2,650	5,300	13	26
Eaton	375,000	25,000	400,000	4,000	8,000	11	21
Branscomb	20,300	10,500	30,800	1,970	3,940	19	38
English Ridge 16/	1,200,000	400,000	1,600,000	10,800	21,600	3	5
Upper Mina	260,000	100,000	360,000	7,400	14,800	7	15

14/ Nominal figures are used, based upon data available in October 1962.

15/ Assuming a sediment yield of 1.00 acre-foot of sediment per square mile per year. Suspended sediment flow figures are shown in Table 8.

16/ A good deal of sediment movement into English Ridge would be arrested in Lake Pillsbury. Current rate of sediment deposition is 0.2 percent (of gross storage) annually. Sediment inflow to English Ridge was adjusted to account for sediment retained in Pillsbury.

It should be realized that Table 8 excludes the flow of bed load material which is as yet unmeasured for any stations in the Eel River Basin. Generally, the bed load varies from about 10 to 50 percent of the suspended load, although in some instances it can exceed this estimate.

In comparing the sediment production figures in Tables 7 and 8 with adjacent areas, the results of reservoir sedimentation studies can be utilized. Reservoirs on the west side of the Sacramento Valley have accumulated sediment at an average rate near 0.20 acre-feet per square mile per year.[17/] The several examples of small reservoirs in the North Coastal area filling with sediment during the first year of operation are not necessarily attributed to poor land use and subsequent erosion, but are also the expected engineering result of constructing a small reservoir on a large stream.

It can be noted that only Jarbow Reservoir would be in danger of exceeding its given dead storage within the customary repayment period of 50 years. However, project planners should not be lulled into a feeling of complacency, as sediment retention problems can result even with large storages. If recreation, including reservoir fishing, is accepted as a valid use of reservoir waters, actual benefits would undoubtedly decrease with increasing sediment deposition. Finally, when the dead storage space was filled, drawdown to this level would reveal a flat of mud; stranding aquatic life and presenting an unpleasant appearance.

Nor can it be assumed that all deposition of sediment would occur in the storage below the lowest outlet. Typically, the larger pieces of bed load are deposited at the head of the reservoir, where the stream makes its

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17/ Brown, Carl B. and Thorp, Eldon M. "Reservoir Sedimentation in the Sacramento-San Joaquin Drainage Basins, California." United States Department of Agriculture, Office of Research, Sedimentation Section, Special Report No. 10. 69 pp. (mimeographed) July 1947.

TABLE 8

SUSPENDED SEDIMENT DISCHARGE SUMMARY

Station	Drainage area (square miles)	Average annual suspended sediment flow	
		Tons per day	Ac-ft/mi^2 18/
Eel River above Dos Rios 19/	703	5,230	0.75
Middle Fork Eel River at Dos Rios	753	6,980 20/	0.94
Eel River at Scotia	3,113	21,120	0.89
South Fork Eel River near Miranda	537	11,390	2.15
Van Duzen River near Bridgeville	214	6,170	2.92
South Fork Eel River near Branscomb	44	177	0.41

entrance. Thence, density currents carry the load of fines to the reservoir bottom, and accumulation in dead storage takes place. In this manner, active storage can be affected, and the reservoir operation altered.

When the sediment load contains a high percentage of fine particles in the clay range, a different problem exists. Rather than the deposition of sediment, the storage of muddy water becomes a problem. The transfer of Eel River waters to storage locations in the Sacramento Valley has been a considered plan of water export. However, it would be undesirable indeed to send muddy waters to the Sacramento Valley, and to recreate problems similar to

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18/ Acre-feet by weight assuming 165 pounds per cubic foot (particle density of quartz grains). Stored in reservoirs, or as soils on land surface, actual density would vary between 20 and 110 pounds per cubic foot.

19/ This figure does not include sediment trapped in Lake Pillsbury, which accumulates sediment at an average annual rate of 0.71 acre-feet per square mile.

20/ Computed using the arithmetic mean of three years monthly totals. Daily records not available.

those encountered on the Russian River in the winter of 1961-62, resulting in part at least, from storage provided in Coyote Reservoir on the Russian River of muddy waters, both native and imported (see subsequent discussion under Corbin Creek).

The most desirable plan with respect to sediment in the Eel River Basin would be to keep the soil on the land. The occurrence of natural erosion should be recognized, but man-caused erosion should be kept to an absolute minimum.

Other Water Management Considerations. If urban areas anticipate the development of surface water supplies for domestic use, the feasibility of acquisition and/or exclusion of tributary lands for management as a municipal watershed should be investigated. While activities on the watershed may have uncertain effects upon the water yield of the area, the unnatural loss of soil and the impairment of water quality through indiscriminate grazing, timber harvesting, and roadbuilding can be avoided only with careful land management. The reduction of the necessity for degrees of water treatment can result in definite reductions of expenditures.

Often the control of snow placement and melting is presented as a use of vegetative manipulation, and a positive item in the watershed management concept. Research on this topic has been conducted in several different locations for a number of years, and the results from a water conservation viewpoint are moderately encouraging. In the Eel River Basin, an extremely small percentage of the total area is subject to extensive snowfall, and there are no permanent snowfields of any major consequence. Thus, snow management through timber management, if an actuality, would be possible but of limited importance.

Special Considerations

Roads. In any lands developed by man, roadways are in most cases an indispensable item in the transportation system. Although in the historic past rivers were used as the main artery of traffic, the modern age and the development of motor vehicles has made necessary a fine network of roads of all kinds. The Eel River Basin contains various types and conditions of highways, from freeways to jeep trails, and almost all have contributed to man's welfare in access and transportation. There have, however, been negative effects of these, although they are not universally recognized as such.

Pioneering roads usually conformed closely to the landscape. They followed game trails, ridges, or bottoms, were neither graded nor excavated, and were the manifestation of the "path of least resistance" from one point to another. The twentieth century has brought high-speed vehicles, the development of remote areas, and economic haul considerations which have altered roadway needs, and thus their design and construction. This change has necessitated lower grades, wider beds, longer curves, greater sight distances, with consequent alterations in amounts of soil moved, drainages crossed, and areas paved. While the early roads were in relatively close harmony and concord with the land, the more modern ones have caused a sufficient amount of accessory disturbance to have a noticeable effect on the soil resource in some areas.

The very act of constructing a modern roadway has several direct and indirect effects upon watershed management considerations. Most obvious is the wholesale movement and exposure of soil, and the emplacement of surplus volumes. When constructed along a stream, many times fill is deposited in the channel, encouraging sediment pickup at high flows and often causing

channel constriction. This constriction of the channel can deflect flows to the opposite bank, creating channel erosion at that point. When a route is cut through a potential slide area, often an attempt is made, wisely, to drain the critical portion to avert movement. However, examples can be found where this drainage facility (through pipes) empties onto exposed slopes, and gullies are carved in the remaining slope.

In an excellent treatise on the location of roads in unstable geology, Rockey and Bradshaw[21/] cited the following effects that road construction might have on the stability of potential landslides:

"1. Restriction of ground water flow by side hill fill.

2. Overloading of relatively weak underlying layers by fill.

3. Overloading or removing support of sloping bedding planes by heavy slide hill fills or cuts.

4. Oversteepening of cuts in unstable rock or soil. (This is brought about by sloughing of cut bank, making the remaining slope steeper, which in turn causes more sloughing.)

5. Removal, by cut, of mantle of pervious soil, if the latter is a natural restraining and drainage blanket over a softer strata.

6. Increase in seepage pressure by cut or fill that changes direction or character of ground water flow.

7. Removal of a mantle of wet soil by side hill cut. Such a cut may remove toe support, causing soil above the cut to slide along its contact with bedrock."

Because of compaction by vehicular pressure or because of paving, very little infiltration or detention of rainfall occurs on the road surface. Consequently, drainage occurs down the more major roadways or in ruts on the lower echelon roads, causing abnormal amounts of water to be collected and

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21/ Rockey, R. Eugene, and Bradshaw, K. E. "Assessing Soil Stability for Road Location on the Six Rivers National Forest, California." United States Department of Agriculture, Forest Service, San Francisco. 39 pp. 1962.

concentrated at a point, and finally to be dispersed over a bank. If not properly conducted to a permanent channel, erosion of the receiving raw bank follows, until a graded channel is formed to accommodate the flow. There are numerous examples of this on highways of all standards in the Eel River Basin, and it is perhaps the most easily observed indication of incomplete highway drainage.

When crossing small waterways, culverts often are used to conduct the streamflow under the roadway. Ideally, the culverted section of the channel should follow the original streambed throughout its entire length, but in practice the outlet is sometimes elevated, and the kinetic energy of the moving water scours out fill, bank, and channel bottom, sending sediment downstream and threatening the stability of the embankment. This, too, is a frequent sight on highways and roads of the Eel River Basin. An example is shown in Photo 7 .

The problems of erosion triggered by roads is least on the major thoroughways of the Eel River Basin. Culverts and drainage facilities on Highway U. S. 101, for example, are usually well planned and constructed, although exceptions can be found. However, the problems seem greatest on seldom-traveled, semi-improved county roads, and on some mountainous forest roads. The primitive "path of least resistance" road is still of minor concern, except where directly connected with a logging operation or up steep grassy slopes.

Thus, roads can have detrimental effects because of exposed soils and cut slides, altered micro-hydrology, and channel alterations from stream crossings. The effects are erosion, which is concerned with land use and highway maintenance, and sediment transport, which is involved with the many

. Culvert with high outfall along the Dos Rios--Laytonville Road, Mendocino County.

aspects discussed under Sediment. Although these occurrences are seldom of a large scale locally, they are quite numerous throughout the Eel River Basin, and their net effect must therefore be assessed as significant.

Redwoods. The Eel River's most widely known resource is the coast redwood, which attains maximum growth in bottomlands of the lower reaches. News items concerning redwoods appear nationally and even internationally, and concern over their husbandry is felt in all corners of the country.

Because this resource is unique, old, and somewhat rare, it is of great interest. Much of the existing preserved park lands have been acquired and presented to the State for care by the efforts of the Save-the-Redwoods League, which in turn has obtained the necessary funds through public solicitation. The State then has a moral obligation to the national public to maintain and preserve these lands in a suitable condition so that they may be enjoyed.

The use of these lands is primarily for recreation, and management through preservation is a valid means of deriving human benefits. The failure to harvest a physical crop is not necessarily the insignia of waste. The products of these redwood lands are recreational benefits of a high quality to those who seek them -- contemplation, satisfaction, and spiritual awareness.

Bull Creek. Bull Creek, a 42-square mile drainage in the redwood belt near Weott has gained notoriety in recent years because of problems incurred in the management of its soil, water, and vegetation. Annual precipitation on the drainage varies from 55 to 115 inches. Although the soils and underlying bedrock in the area are weak and unstable, the topography rough and steep, and land use demand intense, there is a potential for growing commercial timber.

The drainage can be subdivided into two areas. The first is the lower area, consisting of the 8,000-acre Rockefeller Forest, acquired by the State as part of Humboldt Redwoods State Park in 1931 through the generosity of John D. Rockefeller, Jr. Included within this area is Bull Creek Flat, where the most magnificent part of the forest occurs on about 800 acres of alluvial land along the creek. The second part of Bull Creek Basin is the upper watershed, amounting to about 18,000 acres. This was in a large number of relatively small ownerships until 1962, when much of it was acquired by the Save-the-Redwoods League. About 13,000 acres of the watershed lands were donated to the State Park by the League in January 1963.

Use of the lands in Bull Creek undoubtedly began with the first settlement in central Humboldt County, the uplands being utilized primarily for grazing. Lands tributary to the Bull Creek flats were frequently burned, both accidentally and in an attempt to improve range conditions. Log jams were recorded in Bull Creek in the early 1930's, but it was not until the late 1940's that full use of the lands began.

A demand for Douglas fir timber became felt in 1947, and shortly thereafter private interests began timber harvesting operations in the uplands of Bull Creek. In 1955, a devastating fire occurred, followed by the tremendously intense storm of December 1955, which produced a peak flow estimated at 16,400 second-feet at the mouth of Bull Creek. Many areas, freshly stripped of cover, disturbed from logging, and laid bare by the fire, began to erode in a spectacular fashion. Large amounts of material were washed off the slopes and into the Bull Creek channel. The streambed through the Rockefeller Grove reacted to the sediment load and flows by aggrading considerably, and by expanding the channel transversely into the adjacent grove of redwood trees. To date, over 500 trees have toppled into the creek bed, further complicating the problem by obstructing flood flows. Concurrently, the salmon runs up Bull Creek have declined drastically.

Thus, the problem has two aspects: the aggradation of the streambed with consequent damage to the state park, and the erosion of the upper watershed lands. The first is highly dependent upon the second. Remedial work has consisted of an emergency levee at the town of Bull Creek and channel clearing, shaping, and bank protection in the Bull Creek Flats, and the installation of grade control structures above the state park. The essence of the problem -- the instability of the soils in the upper basin -- has not been directly dealt with, and with the exception of selected plantings, the area will be allowed to revegetate by natural means. With the recurrence of severe storms, the on-site problem is expected to continue for years, until at some future date the upper watershed is again stabilized.

Corbin Creek. Corbin Creek is a 44-square mile timber and brush covered drainage tributary to the main stem of the Eel River above Lake Pillsbury. In recent years, erosion prompted by roadway construction in this drainage has become more prevalent, and has been checked only through expensive remedial measures. Further notoriety was gained when a portion of the sediment produced found its way into a newly constructed reservoir, and contributed towards damaging downstream fishing. Although this area's erosion contributed only an estimated ten percent of the total damaging sediment and the reservoir problems are largely independent of this upstream erosion, a review of the situation can serve to demonstrate what could possibly happen on a larger scale in the future.

With the exception of about 4 square miles, all lands in Corbin Creek are federally owned and under the management of the Mendocino National Forest. Soil cover is largely of the Sheetiron and Maymen Series, timber and brush soils respectively. Up to the late 1950's there had been little activity in the drainage, although in 1920 a 1,000-acre ground fire on the

northern dividing ridge partially occurred in Corbin Creek. A number of smaller fires, none of which exceeded 40 acres, have taken place in the area.

Timber harvesting activities began in 1955 with the logging of 1,000 acres of private land in the upper extremes of the north end of the drainage. In 1956, 8,000,000 board-feet of timber were removed from 800 acres of National Forest land in the Lost Camp timber sale, also at the upper extremes of the drainage. All but about 3 miles of spur roads built during the sale were reseeded with grass, and taken out of use. During 1958, 1959, and 1960, the Corbin Creek timber sale removed 36,200,000 board-feet from 4,630 acres in the lower elevations of the basin. An accompanying 9.4-mile section of permanent road (16 feet wide) which would accommodate speeds up to 30 miles per hour, was constructed from Ivory Mill Saddle to Five Springs Creek. During 1960 and 1961, Glenco Forest Products Company harvested 12,000,000 board-feet from 540 acres of their land, and constructed a half mile of road across the federal lands for access.

During 1961 and 1962, further volumes of timber, amounting to 12,200,000 board-feet, were removed from National Forest lands in the Lower Corbin Creek timber sale. More than 4 miles of permanent road along Corbin Creek were built to closely approach the upper main stem of the Eel River. This road, scheduled for "Forest Highway" classification, is a trans-forest route, and was not created to serve solely in timber harvest operations, but for a multiplicity of uses.

The design and alignment standards required on the Corbin Creek road necessitated numerous cuts through unstable soils, and the crossing of many side drainages. Winter storms eroded the road cuts and fills, plugged

culverts, and wetted slide areas, with the end result that a great deal of fine sediment found its way into Corbin Creek, and downstream into the Eel River.

Sediment from Corbin Creek along with clays from other sources were partially retained in Lake Pillsbury and Van Arsdale Reservoir and were then transferred to the Russian River drainage through the Potter Valley tunnel. Impoundment of these waters in Coyote Reservoir did not result in appreciable settlement. Tributaries to the Eel River below Lake Pillsbury and the Russian River also contributed to the inflow of muddy waters. As there was very little significant settlement in Coyote Reservoir, the reservoir merely provided the storage in time of muddy waters, and later releases from the lower levels of the lake colored the Russian River flows during a longer period than in the past. This unusual combination of erosion, sediment transport, retention, and release caused a general decline in salmon fishing on the Russian River, and a great deal of public concern was voiced over the now evident result.

In response to the recognition of their role in the problem, the U. S. Forest Service initiated special erosion control measures on the Corbin Creek road in September 1961. The work during 1962 included the resloping of sliding banks, installation of additional culverts, debris removal, seeding of raw slopes, and other remedial measures to stabilize exposed soil. At the time this report was written, the remedial work had cost $124,000 and is believed to be successful.

Thus, the overall problem has two components: the production of fine sediments in tributary upstream areas, and the storage of the resultant muddy flood waters for release during a normally clear season. The first was

caused in part by timber harvesting activities on Corbin Creek[22/], with the need for and the construction of a high standard road resulting in hydrologic disorders on a larger scale. The second is a natural result of the operation of a reservoir (Coyote) for flood control purposes, although some latitude in operation does exist.

It should be pointed out that both the production of the fine sediments and its subsequent detention was necessary for the problem to be recognized. Furthermore, Corbin Creek was not the sole contributor of sediment to the Eel and Russian Rivers. There is reason to believe that the Russian River problem would have occurred even with the exclusion of all use on Corbin Creek, since the Russian River receives sediment from numerous other sources in the Eel and Russian River Basins.

The on-site problem may have been partially avoided by sacrificing haul economics in the road design, or by not building a road at all. The use of the land was a calculated risk, weighing use-damage probabilities against the alternate of nonuse. To be sure, all reasonable precautions should be taken in similar situations in the future and more enlightened geologic services can be used to material advantage. But it should also be recognized that this problem is merely the manifestation of a price in soil that was paid for access.

22/ The Corbin Creek drainage contains several slides which predate the initiation of logging, and are believed to be of natural origin. Corbin Creek contributions of sediment to Coyote Reservoir have been estimated by the U. S. Forest Service at 10 percent of the total.

8. A gully through grasslands in upper Yager Creek, directly downstream from a highway culvert.

CHAPTER IV. RESPONSIBILITIES OF STATE AND FEDERAL AGENCIES WITH RESPECT TO WATERSHED MANAGEMENT

Because of the long-range aspect of considerations of land use, "government" in general, and its agencies in particular have been allotted the task of leadership in this field. With the existing land use in the basin, the question of the stewardship of its resources arises. The examination of the agency system of management, and the partial enumeration of duties should reveal both overlap of present coverage, voids in which no responsibility has yet been assigned, and areas in which no legal concern has, as yet, been interpreted by any agency.

State Agencies

Department of Fish and Game. "Broadly speaking, the Department of Fish and Game is responsible for the protection, maintenance, enhancement, and management of the fish and game resources of the State.... In carrying out these responsibilities, the Department of Fish and Game becomes directly involved in the management of the land and water resources upon which the fish and wildlife resources are completely dependent."[1/]

As vehicles for the implementation of their responsibilities, a number of sections of the Fish and Game Code concern watershed management. These are enumerated and briefly described below.

Section 5650 provides that it is unlawful to deposit in, permit to pass into, or place where it can pass into the waters of the State a number of substances which are specifically named which are deleterious to fish life, and in addition, any other substance or material deleterious to fish, plant, or bird life.

1/ State of California. "Pollution Control Responsibilities of the California Department of Fish and Game." 15 pp. (mimeographed) 1961.

Section 5651 gives the Department of Fish and Game the responsibility for reporting a condition of continuing and chronic pollution to the appropriate Water Pollution Control Board and to cooperate and act with that board in taking steps to enforce Section 5650.

Section 5652 makes it unlawful to dispose of trash, garbage, or rubbish within 150 feet of the high-water line of any inland water of the State.

Section 5653 requires operators of vacuum or suction dredges to report details of proposed operations to the Department of Fish and Game and obtain a permit.

Section 12015 requires anyone convicted of unlawfully polluting, contaminating, or obstructing waters to the detriment of fish life, to remove any removable substance causing the pollution or pay the costs of such removal.

Sections 1601 and 1602 provide for review by the Department of Fish and Game of any water projects planned by public or private organizations, which would disturb the streambed, and provide for subsequent recommendations by the department as to measures necessary to protect fish and wildlife.

Thus the Department of Fish and Game is primarily concerned with that which affects the fish and wildlife of the State. Efforts have centered around the pollution of waters, although it is openly acknowledged that the present legislation is insufficient to satisfy needs of regulation on the excess movement of soil and logging debris into salmon spawning streams.

Division of Forestry (Department of Conservation). The several responsibilities of this agency render it of prime importance in effecting goals of watershed management aims. Its main function for the past several decades has been that of fire prevention and suppression to varying degrees, presently covering about 35.6 million acres of land throughout the entire State. An efficient and well organized system of detection, eradication,

and education has been established, and is frequently referred to as one of the nation's best. In general, neither federal lands nor incorporated urban areas are under state protection, although exchange contracting on some protected land does occur.

The Division of Forestry is also responsible for a range improvement program which consists mainly of a system of control measures on planned range and brush burns. Provisions require burners to obtain permits from the division during the fire season, and allows for standby crews to insure the safety of adjoining lands. A range improvement advisory service is also available under this program.

A program for the emergency vegetation of denuded watersheds is available in freshly burned areas. The division cooperates with soil conservation districts, water and flood control districts, and local and federal agencies in this matter. The treatment usually consists of aerial seeding of fast growing annuals. The State shares 50 percent of the cost, which has averaged about $1.50 per acre up to 1961, and also furnishes technical guidance, makes the arrangements, and evaluates prior trials. The treatment is designed as minimum soil protection and has been done for the most part in Southern California.

The State of California, through the California Division of Forestry, has provided the entire support for the State Co-operative Soil-Vegetation Survey, from its inception in 1947 to date. The actual work of the survey is performed by the Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service, (field survey and map compilation), and the University of California (laboratory analyses of soils and field and laboratory soil fertility studies), under contract to the State of California, Division of Forestry, for which they are reimbursed in full. The lands of Mendocino National Forest were not included in this survey because the U. S. Forest

Service did not choose to participate in or contribute to the survey. The Trinity County portion of the Eel River Basin should be completed about 1965.

The Division of Forestry was responsible for the recent initiation of a research project in the North Coastal area, the Caspar Creek Watershed Study in the Jackson State Forest near Fort Bragg. The project was established cooperatively with the California Department of Water Resources, Department of Fish and Game, and the Pacific Southwest Forest and Range Experiment Station of the U. S. Forest Service. This work seeks to inventory natural sediment and water production on an undisturbed drainage, and by means of judiciously planned logging, determine the effects of such actions on yield, flood peaks, sedimentation, and fisheries habitat. So far is known, this is the first such work ever conducted in the North Coastal area. Preliminary results from the inventory phase should be available about 1966.

A Service Forestry program is carried on by the Division, in which the Service Forester assigned to the Humboldt Ranger Unit works with small timber and land owners to advise them on desirable timber management practices, including minimizing soil losses from timber lands through erosion control measures on logging areas and in logging road and skid road construction.

The Forest Practice Act is included in Sections 4901-4974 of the Public Resources Code. The Act was adopted by the State Legislature in 1945 as a result of the Joint Interim Forestry Study Committee recommendation that "legislation was necessary to establish minimum standards for commercial timber cutting".2/

The Act divided the State into four geographic forest regions,3/

2/ Arvola, T. F. "Forest Practice Regulation in California." Journal of Forestry, 60:12. pp. 872-6. December 1962.
3/ Public Resources Code, Section 4926.

thus recognizing the diversity of forest conditions in the State. The central purpose of the Act is to conserve and maintain the productivity of the timberlands in the interest of the economic welfare of the State and the continuance of the forest industry.

In 1947 a separate set of forest rules was adopted for each of the four forest districts. These rules are concerned with (1) fire prevention and control, (2) protection of timber growth and soil productivity, (3) prevention and control of damage by forest pests, and (4) measures for restocking the land.

The Act, as originally enacted, provided no measures or penalties for purposes of enforcement. The State Forester was required to make inspections of timber operations. Emphasis was upon education and personal persuasion. The Act has been amended several times and the rules have been amended twice to meet changing conditions, to improve rule standards, and to strengthen enforcement features. In 1953 erosion control requirements became a part of some district rules and by 1960 all districts had rules to minimize soil erosion on timber operations. Points of special concern to the general public over the years have included difficulties of enforcement due to cumbersome legal processes, lack of orientation of the program toward the timber owner as well as the timber operator, recognition of timberland primarily as a site for timber growth with limited interest in the protection of fisheries, recreation, and other values unless they affect forest productivity. Also of concern were provisions of the Act which allow clearcutting upon filing of an affidavit by the timberland owner of his intentions to devote the land to purposes other than growing timber. The 1963 amendments of the Forest Practice Act improved some of these features.

Over the past 17 years considerable improvement in forest practices has been accomplished in California through regulation - from a time when little control existed until the present when at least minimum practices are required. Under the Forest Practice Act as amended in 1963 the State Forester may deny a timber operator's permit or renewal of a permit because of failure of applicant to comply with the forest practice rules. This provision should be very effective in obtaining compliance with the rules but it is too early yet to fully evaluate its effectiveness.

Division of Soil Conservation (Department of Conservation). This agency is primarily responsible for the execution of two functions, each of which is administered by a separate section. The two functions are Program Development and Watershed Planning. Program Development promotes Soil Conservation Districts throughout the State and administers A.B. 1144.[4/] The work is done by field representatives who maintain close contact with rural organizations and advise them of the availability of various federal and state aid programs. A.B. 1144[4/] is a grant-in-aid program, funded by an annual appropriation. In the past this has amounted to $100,000 annually. The grants are given for a wide variety of conservation projects and usually require that some percentage of the granted amount be contributed by the grantee.

Watershed planning for Public Law 566[5/] projects is carried out at several levels by an engineering staff in the division. The division conducts field reviews, makes reconnaissance investigations, and prepares

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4/ Public Resources Code, Section 9063.1.
5/ Watershed Protection and Flood Prevention Act, 68 Stat. 666; 16 U.S.C., Sec. 1001 et. seq.; 1958 ed.

watershed work plans for local districts, final submission being to the federal authorities. The division is the State's technical representative in dealing with the U. S. Soil Conservation Service in matters involving this act.

Under certain conditions the Division of Soil Conservation can undertake special contract work for other state agencies. Of particular interest in the Eel River Basin is a report prepared under such a contract with the Division of Beaches and Parks on flood control and erosion problems in the Bull Creek watershed (Humboldt County) in 1961.

Division of Beaches and Parks (Department of Parks and Recreation). This agency is concerned with the acquisition, care, and management of scenic, recreational, and historic areas throughout the State. In the Eel River Basin, the diversion deals almost entirely with redwood lands in five separate units. These are Humboldt Redwoods (approximately 37,000 acres), Grizzly Creek Redwoods (150 acres), and Richardson Grove (796 acres) State Parks; and Admiral William H. Standley (45 acres) and Benbow Lake (223 acres) State Recreation Areas.

Although there are different principles of management for the State Parks and the State Recreation Areas, these are largely preservational in nature in both cases, which is in accordance with the objectives for which they were established. This policy is also in harmony with the aims of the donors of the redwood lands, the Save-the-Redwoods League. As most of the redwood lands in state parks in the Eel River Basin are in near-virgin conditions, only a minimum of concern over watershed management is generally felt. The outstanding exception is, of course, the flood, erosion, and

debris problems on Bull Creek in the Humboldt Redwoods State Park. The origin of this problem was, however, on private lands above and outside the park, and is currently being solved through the acquisition of these lands for restoration and protective custody.

State holdings of redwood lands in parks will undoubtedly increase. Almost all the lands in the upper extremes of Bull Creek are being obtained by the Save-the-Redwoods League and donated to the State. Other scattered redwood tracts are also periodically purchased and donated. This acquisition and donation program is expected to continue.

Department of Water Resources. The primary objectives of the Department of Water Resources are:

1. To plan for and guide the development of California's water resources, subject to laws and executive orders, to the end that the water needs of the people of California may be met most effectively, economically and equitably; and

2. To construct and operate physical works associated with this development where authorized to do so by the Legislature, and to support and encourage such construction and authorization by other agencies where appropriate.

The department has many obligations and responsibilities concerned with the general fields of planning, construction, operation, administration, and inventory.

The Upper Eel River Development, selected as the first addition to the State Water Project in the North Coastal area is of great importance to the

Eel River Basin. This project will consist of dams and reservoirs with appurtenant transfer facilities. While the projects concerned will be comprised strictly of engineering works, their development and operation will result in certain unavoidable interactions with the soil and vegetative resources which can be determined only approximately.

In an effort to encourage and assist in local water development and conservation, the Davis-Grunsky Act was enacted in 1959.6/ Its administration is handled by the Department of Water Resources.

Briefly, the aims of the Davis-Grunsky Act are to:

1. Provide state loans to public agencies for construction of local water projects when such agencies are unable to obtain financing on reasonable terms from other sources.

2. Encourage development of the recreational and fish and wildlife potentials of local water projects by making state grants for such purposes.

3. Enable the State to participate as a partner in the development, construction, or operation of local water projects, where such participation is necessary for optimum development of the resources.7/

This program was not intended to compete with private sources of financing, or with other governmental aid programs. The State's role was conceived as one of "filling the gap," where private or governmental sources proved to be inadequate or inappropriate. As of October 1, 1963, although 76 requests for determination of eligibility have been filed under the program,

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6/ Ch. 1752, Stats. 1959.
7/ State of California. "State Financial Assistance for Local Water Projects Under the Davis-Grunsky Act." The Resources Agency of California. 33 pp. 1962.

only 22 formal applications have been filed, and of these only 13 have been approved for a total of $2.9 million in loans and $6.8 million in grants.

The Department of Water Resources performs as the State's official reviewing agency for most federal agency reports of water development plans in California. The State's interest lies not only in the optimum development of the water resource and coordination with The California Water Plan, but also in the review of lands, easements, rights-of-way, and relocation costs[8] as well, since these costs are borne by the State for authorized flood control projects.

Several water inventory functions are performed, some in cooperation with federal agencies, by the department. These include measurements of flow, and water quality, and suspended sediment in cooperation with the U. S. Geological Survey, precipitation with the U. S. Weather Bureau, ground water and waste water discharge.

A currently active Coordinated Statewide Planning Program seeks to: (1) determine the water supply, present water uses, future water requirements, and resulting surpluses or deficiencies for given drainages; (2) integrate time and economics into the evaluation of future water requirements, develop basic data to determine need, project sizing, economic justification, and financial feasibility; and (3) provide for continuing reappraisal of project capabilities. In short, it will determine how much water an area has, how much it needs, and when the water should be delivered to it. A report covering this program in the Eel River Basin is presently being prepared, and should be completed within a year.

Other duties of the department include special investigations for other state agencies. Such investigations run the gamut from water supply

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8/ State Water Resources Law of 1945, Water Code, Div. 6, Part 6, Chapters 1 and 2.

studies for work camps or ranger stations to special investigations requested by the Legislature to emergency flood control and monitoring services.

Division of Highways (Department of Public Works). The basic responsibility for planning, constructing, and maintaining of State Highways is vested in the California Division of Highways, a unit of the Department of Public Works. Authority in the Division of Highways is centered in the State Highway Engineer who has delegated many of the management and engineering functions of the Division to District Engineers in each of 11 districts of the State. The entire Eel River drainage falls within the bounds of District I, headquartered in Eureka. In exercising this authority, consideration is given to some items of importance to watershed management. Some examples of these are the location of highway drainage structures, the crossing of slide areas, the exposure of slopes to erosive forces, and in limited instances the disposal of spoil into live stream channels (generally resorted to only in emergency situations).

Although the Division of Highways has several manuals covering all phases of planning, construction and maintenance, each of which deals to some degree with the previously mentioned features, there are three guides used by the division which deal specifically with these features. These publications are "California Culvert Practice,"[9] "Bank and Shore Protection in California Highway Practice,"[10] and "Erosion Control on California State Highways."[11]

The location, selection and type of drainage structures to be used in any given instance is treated in "California Culvert Practice" and "Bank

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9/ State of California. "California Culvert Practice (Second Edition)." Department of Public Works, Division of Highways. 119 pp. 1944.

10/ State of California. "Bank and Shore Protection in California Highway Practice." Department of Public Works, Division of Highways. 423 pp. 1960.

11/ State of California. "Erosion Control on California State Highways." Department of Public Works, Division of Highways. 71 pp. 1950.

and Shore Protection in California Highway Practice." The specific design of structures is covered in greater detail in planning manuals of the Division of Highways. These publications and manuals are used as guides to assist in proper selection and design. Soil stability and erosion control must be considered in such selection and design. The overall objective is protection of the highway and of the abutting property. This objective ordinarily results in proper treatment from the standpoint of watershed management.

Erosion control on slopes is discussed in "Erosion Control on California State Highways." This publication covers standard erosion control measures for soils exposed during highway construction, and control measures for a number of different situations are suggested. The objectives of this publication conform closely to good watershed management objectives.

In the design and construction of state highways, all reasonable attempts are made to avoid areas of questionable land stability; however, on occasion complete avoidance of these areas by the Division of Highways is difficult, if not impossible. In these instances, potential slide areas are investigated and the design of slopes and grade lines are based on the results of these studies. As might be expected, every reasonable effort is made to minimize construction and maintenance problems. There are, however, instances where, in spite of these efforts, some placement of loose soil material into a live stream may occur, particularly when emergency action is dictated in the removal of slide material. This occurrence can adversely affect any existing fish population; however, an interagency Memorandum of Understanding has been executed which provides, among other items, for the consideration of corrective action once the emergency status is past.

The Memorandum of Understanding between the Department of Public Works and the Department of Fish and Game recognizes the effect of highways

on the wildlife resources of an area. This memorandum allows for appropriate review of highway plans as they may effect fish and wildlife by the Department of Fish and Game. This agreement is primarily a cooperative instrument and although final design decisions are retained by the Department of Public Works, it has been found to be satisfactory. The two state agencies, Fish and Game and Highways, report no existing areas of serious conflict between highway and wildlife projects.

The process of highway planning requires a great deal of judgment and inevitable failures occur because of a human inability to adequately envision all resulting consequences, and because of the infeasibility of financing projects without some risk.

State Water Quality Control Board and Regional Water Pollution Control Boards. Within California, the responsibility for the prevention, abatement, and control of pollution rests with the state and regional boards. These boards were created in 1949 to provide a means of coordinating the actions of the many government agencies involved in the prevention and control of water pollution and to place control on a local or regional level. These agencies include the Departments of Fish and Game, Water Resources, and Public Health. The state and regional boards can make studies, contract with other agencies to conduct investigations, formulate long-range plans and policies, prescribe waste discharge requirements for existing and proposed sewage and industrial waste discharges, request enforcement of water pollution laws by appropriate public agencies, issue cease and desist orders, and initiate court action if persons fail to comply with corrective orders.

Through the efforts of government agencies, instances of pollution and contamination have been prevented or abated throughout the Eel River watershed. Although pollution can be prevented through proper use of the pollution control laws, impairment of these waters can be expected to occur.

Reasonable impairment from both industrial and domestic wastes, which is now occurring, can be expected to increase with continued development and associated population increases. This impairment will probably result in increases in the mineral content and turbidity of the river waters and could result in significant temperature changes.

Although the pollution control laws are quite broad and comprehensive, there appears to be some question whether they cover water quality impairment created by erosion which is aggravated and unreasonably increased by uncontrolled development. If impairment is severe enough and the cause can be established, action might then be taken through the Fish and Game Code to correct the situation, but controls are needed to prevent the impairment rather than merely to abate it.

Federal Agencies

Bureau of Land Management (Department of the Interior). This agency was created in 1946, combining the activities and organizations of the General Land Office and the Grazing Service. Its function is the management of lands within the public domain, its main efforts centering on grazing and timber management activities but also including mineral and land disposal activities as well. Upon formation of the Bureau, range management activities were continued from the original Grazing Service legislation, the Taylor Grazing Act of 1934,[12/] and timber management was authorized on lands within the public domain in the Materials Disposal Act of 1947[13/] and Section 7 of the Taylor Grazing Act. In the Eel River Basin, public domain constitutes an estimated 90,000 acres of generally lower quality lands, scattered in a somewhat random

12/ 48 Stat. 1269; 43 U.S.C., Sec. 315 et. seq.; 1958 ed.
13/ 61 Stat. 681; 30 U.S.C., Secs. 601-604; 1958 ed.

fashion throughout the Mendocino and Trinity County portions of the drainage. Some public domain lands are, in fact, contiguous to the Mendocino and Six Rivers National Forests.

Although a valid function of the Bureau of Land Management has historically been the disposal of public domain to private ownership, the recent trend has been toward the conscientious management of these lands. Most of the timberlands are managed on a sustained yield basis, and sales are handled on a bid system accompanied by stringent logging contracts. However, grazing rights, because of provisions of the Taylor Grazing Act, are handled on what might be termed a preferred rights system, whereby local or adjacent landowners are given preferential grazing privileges. The fees are acknowledged to be significantly lower than competitive local private grazing charges, but this apparent subsidy is well within the spirit of the Taylor Grazing Act.

Considerations of watershed management are woven into timber and grazing management plans. However, there is a "Soil and Moisture" program organized as a part of the grazing function, which promotes the rehabilitation of damaged or otherwise eroded public domain lands. There are no known Bureau of Land Management rehabilitation projects in the Eel River Basin at present.

Forest Service (Department of Agriculture). The primary mission of the U. S. Forest Service is the protection, development, and management of the National Forests which are assigned to their care. Because of this obligation, the Forest Service is directly concerned with timber, range, recreation, wildlife, and watershed management. This agency has direct management responsibilities for about one-fifth of the Eel River Basin.

The first "Forest Reserves" were set aside from the public domain under the provisions of the Forest Reserve Acts of 1891[14/] and 1897.[15/] The Forest Service was formed by the Agricultural Appropriations Act of 1901,[16/] which converted the Division of Forestry to the Bureau of Forestry, later changed to the more euphonious Forest Service. In 1905, the administration of the national forest reserves was transferred to the Department of Agriculture, and they were renamed National Forests. The Forest Service, soon after its formation, "became recognized as one of the most efficient bureaus in Washington, with an espirit de corps that was unmatched."[17/] This legacy and reputation has followed to the modern day.

The basic land unit of Forest Service administration is the Ranger District, and its manager is the District Ranger. Several ranger districts comprise a National Forest; e.g., Mendocino, which is administered by a Forest Supervisor. Regional supervision of the National Forests is by a Regional Forester (San Francisco) and national administration by a Chief Forester (Washington). Portions of the eastern mountain area of the Eel River Basin are managed by the Willows, Stonyford, Upper Lake, Ukiah, and Covelo Ranger Districts of the Mendocino National Forest, and by the Mad River Ranger District of the Six Rivers National Forest, grossing about 500,000 acres of which an estimated 425,000 are in federal ownership.

Recent Forest Service policy has been guided by the Act of June 12, 1960,[18/] which made law of its long-practiced management concept of "the greatest good for the greatest number in the long run." Not only a management

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14/ 26 Stat. 1095; 16 U.S.C., Sec. 471 et. seq., 1958 ed.
15/ 30 Stat. 34; 16 U.S.C., Sec. 471 et. seq., 1958 ed.
16/ 31 Stat. 929.
17/ Dana, S. T. "Forest and Range Policy." McGraw-Hill Book Company, Inc., New York. 455 pp. 1956.
18/ 74 Stat. 215.

directive, it also implies responsibility for the stewardship of all the forest resources in combination, and derivation of the maximum net benefit. This policy is intertwined into all decisions affecting the use of lands. It makes mandatory the recognition of all values of land for all uses, and has led to the creation of multiple use plans for all Ranger Districts. Water production is officially recognized by the Forest Services as a valid use of land.

The obvious management of forests for timber has occupied Forest Service attention since its infancy. Timber is managed on a sustained yield basis through development of timber management plans that are consistent with the multiple use plans. Sales of timber are planned by the District Ranger and, depending upon the sale size, are reviewed and approved by staff personnel at higher administrative levels. In this process, contract timber harvesting specifications are written to cover every conceivable situation where associated natural resources might be affected by the operation. The method to be used is specified, as are access road standards, fire control measures, slash disposal, silvicultural considerations, etc. Upon execution of the sale and the initiation of the actual timber harvesting, the operation is inspected periodically by Forest Service personnel for compliance with the contract. Violation of contract specifications by the logger can result in the closure of the operation until the transgressions are corrected.

Range forage is sold by a preference system, wherein privileges to graze National Forests are allocated to previous users of the range, and adjacent and local landowners. This preference can be transferred with the sale of the commensurate property or livestock that form the basis of the preference. Fees charged are often somewhat lower than for competive local private land, as one function of the system is to assist in the stabilization

of the local economy. Fees are developed regionally and adjusted annually based on market conditions.

Provisions for control of grazing on the National Forests are written into the grazing permits and are implemented through grazing allotment analyses and plans. Removal or reduction of grazing pressure for the protection of the range is a practiced management tool, although the range user is provided with an appeal procedure should he feel the adjustments are unwarranted. This control step is sometimes necessary to maintain a sustained yield of forage, which can be considered as analogous to the sustained yield concept of timber.

Watershed management considerations at the district level are accounted for internally in the management of timber, range, and other resources and uses, and through staff review and funding control at the National Forest, regional, and national levels. The review of resource plans provides staff officers an opportunity to suggest changes in management. In this sense, personnel concerned with soil stability and water control function as a conscience for specific land uses.

Congressionally appropriated funds are allocated through the Regional Office to the forests and districts for watershed restoration projects. These projects, which average several thousand dollars apiece, are generally devoted to the stabilization of eroding nonsystem roads, streambanks, and watershed slopes. Funds are also available for the rehabilitation of burns.

Despite sound policies of practice and a close system of review, watershed impairment does occur on National Forests. This usually results because of: (1) an inability to envision all possible circumstances in planning; (2) inadequate research and soils knowledge upon which to base decisions; (3) an excessive concern with economics which sometimes results in minimum programs; and (4) inadequate appropriations to finance urgently needed projects

and staff all activities to give first-class supervision to other resource and development activities.

The Forest Service also performs the vital function of research in wildland management. The disciplines studied include recreation, wildlife, range management, timber management, watershed management, and the use and occurrence of fire. The research varies in intensity and nature, including both basic and applied aspects of the subject matter outlined.

In California, forest research is carried out through the Pacific Southwest Forest and Range Experiment Station centered in Berkeley. Such a location is customary in order to maintain academic contact with universities, to the benefit of both parties concerned. Experimental work is usually conducted on National Forest or other public lands, primarily because scientific control over land use can be exercised in this situation. In watershed management research, the ultimate aim is to measure the effect of land use on the water resource -- primarily with respect to sedimentation, flood control, and water yield. Past watershed management research has been confined entirely to the Sierra Nevada and to Southern California, the most well known locations being the Central Sierra Snow Laboratory at Soda Springs, and the San Dimas Experimental Forest at Glendora.

The Forest Service is actively engaged in a cooperative watershed research project with the Division of Forestry and the Departments of Water Resources and Fish and Game, on the Caspar Creek drainage in the Jackson State Forest near Fort Bragg.

An investigation of the occurrence and nature of landslides in Northern California is in the initial planning stage. This study will not be concentrated in a single location; it will sample slides or potential slides from the entire area. The study will accent the soil moisture, geology, and land use aspects of the problem.

Soil Conservation Service (Department of Agriculture). The Soil Conservation Service (commonly abbreviated as SCS) is the technical soil and water conservation agency of the Department of Agriculture. It is responsible for developing and carrying out a national program of conservation of land and water resources. Its primary job is helping farmers and ranchers, individually or in groups, in conservation work on their lands. Assistance is provided mainly through locally organized soil conservation districts.

The SCS provides technical assistance to other agencies in the Department of Agriculture. The programs include the Soil Bank, Agricultural Conservation Program (ACP), and loan features of the Farmers Home Administration.

Several functions of the SCS are of particular interest to applied watershed management in the Eel River Basin. With respect to the Soil Conservation and District Allotment Act aid program,[19] parts of the Eel River Basin fall into four separate districts. With the exception of Humboldt County, all of the Eel River Basin is included. These districts are referred to as Mendocino County, Westlake (Lake County), Trinity County, and Elk Creek (Glenn County). Servicing SCS offices which aid these districts are located in Sebastapol and Red Bluff. Because of the lack of a Soil Conservation District, very little work is carried out by the SCS in Humboldt County.

The Soil Conservation Service carries out soil surveys to meet the immediate needs of the soil and water conservation programs. Survey reports on specific areas are published, but to date, none have been developed for the Eel River Basin.

Several watershed protection and flood prevention programs are

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19/ 49 Stat. 163; 16 U.S.C., Sec. 590a et. seq.; 1958 ed.

administered through the SCS in cooperation with federal and state agencies. The first of these programs deals with 11 major watershed specifically authorized under the Flood Control Act of 1944,[20] of which two are in Southern California. In these projects the SCS prepares the work plans, installs the structures, and assists in planning soil conservation measures on the tributary drainages. None of these exist in the Eel River Basin.

Fifty-eight small pilot watersheds have been established in 32 states to demonstrate what might be accomplished in the protection of upstream areas from floods, and to show the physical and economic benefits of soil and water conservation measures. These watersheds were also intended to serve as models to gain experience in local-state-federal cooperation in planning work, being the forerunners to projects authorized under the Watershed Protection and Flood Prevention Act.[21]

The Watershed Protection and Flood Prevention Act provides for technical and financial assistance by the Department of Agriculture to local organizations for land treatment, flood prevention, and the conservation, development, utilization, and disposal of water on watersheds up to 250,000 acres in size. This has been the service's most popular comprehensive program to date, although there are no completed or proposed units in the Eel River watershed. There are, however, two completed projects in Sonoma County (Central Sonoma) and in Lake County (Adobe Creek) to the south.

The program was designed to combine land treatment and structural measures for soil conservation and water management, the latter on a smaller scale than previously available through federal aid programs. These projects fill the gap in size between what an individual landowner might be expected to construct by himself and programs available under the administration of the

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20/ 58 Stat. 887; 33 U.S.C., Sec. 701f-3; 1958 ed.
21/ 68 Stat. 666; 16 U.S.C., Sec. 1001 et. seq.; 1958 ed.

Bureau of Reclamation and the Corps of Engineers. Structural measures can be of three kinds: (1) flood prevention measures, which are eligible for federal assistance up to full cost; (2) agricultural water management measures such as drainage and irrigation which are also eligible for federal technical assistance and cost sharing; (3) nonagricultural water management measures -- such as municipal or industrial water supplies, streamflow regulation, or wildlife and recreation facilities -- which are also eligible for cost sharing. However, the installation of approved land treatment must be at least assured before structures can be installed.

While the act has been somewhat of a success in the midwestern states, obvious difficulties have come to light in applying it in California. Together with a limitation on the maximum watershed size of 250,000 acres, the law limits flood control storage in a project reservoir to 5,000 acre-feet. California's characteristic rainfall and runoff pattern does not easily conform to this restriction, and this limitation has proven to be somewhat of a stumbling block. Also, as floods in California are almost entirely limited to winter months, while crops are grown in the summer, it has been difficult to justify a flood control project on the basis of damages to agricultural values. Because of these factors, the application of the law has gravitated towards urban areas in California, which has not been the primary intent of this program.

<u>Bureau of Reclamation</u> (Department of the Interior). Although a major water development agency in the western United States, in the past the Bureau of Reclamation (abbreviated USBR or "Bureau") has been only incidentally concerned with strictly watershed management matters. Attention has been primarily centered on large-scale projects to develop waters for irrigation supplies, and as fits these projects, with flood control, power production, recreation, etc.

In their efforts to supply water to areas of deficiency, the Bureau of Reclamation is conducting studies to export surplus winter flows southward from the Eel River through a system of engineering works. Present Bureau plans are somewhat similar to state-envisioned features currently under study by the Department of Water Resources. Although there are differences in the plans of these two agencies, joint meetings are regularly held to coordinate the respective planning studies.

Construction of reclamation projects is carried out through a number of programs including the program authorized by the Small Reclamation Projects Act of 1956,[22] which fits small irrigation project needs most conveniently. Under this act, total project cost is limited to $10,000,000, and federal participation is limited to $5,000,000. This law is especially attractive in that repayments on capital costs allocated to irrigation are interest free. There are at present no USBR projects of any kind operating in the Eel River Basin, and no small reclamation projects under consideration.

While the Bureau's interest with watershed management traditionally has been only as it affected engineering works, recent federal policy amendments should broaden and increase their activity in this field. The Executive Order of May 15, 1962, (Senate Document 97) affects the coordination of resource development between the Departments of the Interior, Agriculture, Health, Education and Welfare, and Defense, and should give additional latitude to the consideration of such matters as soil stability, sediment production and retention, and land conservation.

<u>Corps of Engineers</u> (Department of Defense). The Corps of Engineers (abbreviated USCE or "Corps") has conducted a program known as the Civil

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22/ 70 Stat. 1047; 43 U.S.C., Sec. 422a-k; 1958 ed.

Functions of the Department of the Army (formerly the War Department), extending back to colonial times. Until the more "recent" years it was devoted solely to the improvement of rivers and harbors for purposes of navigation and national defense. In 1917, activities were extended to include flood control on the Mississippi and Sacramento Rivers and in 1936 were further extended to nation-wide scale.[23]

Although the Corps usually plans and builds large structures such as dams or levees, certain small flood control projects may be constructed without the specific authorization of Congress under provisions of the Flood Control Act of 1948 as amended.[24] This legislation works within the basic framework of the Flood Control Act of 1936,[25] under which most of the USCE work is done. As the maximum federal expenditures under the general authorization provisions are limited to $1,000,000 and the project must constitute a complete solution to the flood control problem involved, this program in Northern California has been limited to small levee systems, and there has been no concurrent water conservation development to date. There is at present one USCE project in the Eel River Basin, a flood control levee built at Sandy Prairie near Fortuna in 1960, but no existing projects under the provisions of the general authorization.

The Corps of Engineers is concerned with watershed management only incidentally and as it might affect flood control structures and navigation maintenance. There is no enabling legislation which allows it to be concerned with upper watershed activities, and construction in the past has been restricted to large dams and levee systems.

23/ Golze', Alfred R. "Reclamation in the United States." The Caxton Printers, Ltd., Caldwell, Idaho. 486 pp. 1961.
24/ 62 Stat. 1182; 33 U.S.C., Sec. 701s; 1958 ed.
25/ 49 Stat. 1570; 33 U.S.C., Secs. 701a-f, h; 1958 ed.

Public Health Service (Department of Health, Education, and Welfare). "The Public Health Service operates under the Federal Water Pollution Control Act of 1956, which provides for the development, in cooperation with other Federal Agencies, with state water pollution control agencies and interstate agencies, and with municipalities and industries involved, of comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground water."[26] To further these aims, the PHS (abbreviation for Public Health Service) offers technical assistance and grants for certain purposes, collects basic data, and carries out a research program and enforcement program. The PHS supports state agencies in water quality management and conservation programs. The value of soil conservation and sediment control as pollution abatement measures is recognized by the PHS in its various activities. However, as interest is limited in the 1956 act to interstate waters, the PHS is not active in the Eel River Basin at the present time.

Bureau of Indian Affairs (Department of the Interior). This agency is the trustee of all natural resources and receipts thereof of Indian lands in the United States. In the Eel River Basin, Indian lands total about 20,000 acres, occupied by about 600 Indians in one reservation (Round Valley) and three rancherias (Laytonville, Sherwood, and Rohnerville). The principal use of the land is for range and timber purposes, which is overseen by technical personnel of the Bureau. Grazing privileges are sold with a preference to Indian users, their fees being about one-half of a non-Indian user's fees. Grazing privileges on lands beyond the Indians' needs are sold on a competitive bid system, but

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26/ Bowering, Reginald, and Spies, Kenneth M., and Neale, Alfred T. and Bullard, William E. "Watershed Control for Water Quality Management." Pollution Control Council, Pacific Northwest Area, (Reproduced by U.S. Department of Health, Education, and Public Welfare Health Service, Portland, Oregon). 36 pp. 1961.

in practice they usually are most economically obtained by adjacent landowners. Profits from logging operations revert to the Indian owners, and where appropriate, are disbursed through the cooperation of the resident tribal organization. Watershed management practices consciously applied for erosion control usually only incorporate the installation of water bars on access logging roads. Generally, culverts are not installed at stream crossings, and roads are not reseeded after use and "put to bed."

The trend in California in recent years has been towards the withdrawal of federal supervision of Indian activities. Thus, it can be anticipated that lands under the management described above will decrease in the future.

Fish and Wildlife Service (Department of the Interior). The River Basin Studies Branch of the Fish and Wildlife Service is the federal agency responsible for reporting on fish and wildlife interests which may be effected by any existing or proposed federal water project. In this capacity, any federal water project (USCE, USBR, SCS) or any other project having federal interest on federal lands, or using federal monies, is investigated from the standpoint of effects upon fish and wildlife values. Its mission then is to study the effects of water development projects on fish and wildlife resources and to recommend measures to project construction agencies for the enhancement of fish and wildlife and the prevention of damages to these resources.

Reports on potential water projects are submitted in project reports to Congress and are embodied in the recommendations of the Secretary of the Interior. The service has no regulatory powers, no aid or grant programs, but performs a minimum of applied research and inventory work. A great deal of its efforts are consumed in essentially consulting work to other federal agencies, namely, the Bureau of Reclamation and Corps of Engineers. Watershed

management is of interest to this agency as it might affect the welfare of the fish and wildlife resources. Although there is a federal interest in the construction and maintenance of highways which receive federal aid, the service is not yet authorized to investigate the effects of such developments upon these resources.

. Bank cutting and sliding along the Van Duzen River between Carlotta and Bridgeville. A probable source of sediment. Note seep in the foreground.

CHAPTER V. WATERSHED MANAGEMENT NEEDS IN THE EEL RIVER BASIN

Although timber harvesting, grazing, roadway construction and the other activities of man in the Eel River Basin have been suggested as the causes of watershed damages, it is a fact of life in our society that the complete cessation of these activities is not a valid solution to the problems. The use of these lands and waters for the production of timber, for grazing, for recreation, for farming, and for access for these purposes is perfectly legitimate, and the people of the State have a valid right to demand that the renewable resources be utilized. These activities must continue to some extent in order for economic and social benefits to be realized from the area.

This concept has been paramount in the development of the resources of the Eel River Basin. By the means that have been legally, morally, and practically available, those concerned with the development of the resources which returned the more immediate financial rewards oftentimes furthered their interests at the overall expense of society. This occurred in part because values of the several resources were not (and are not) measured in identical terms, although they should receive equal consideration in benefits to society.

If a system were devised to compare the values of fisheries, wildlife, recreation, soil stabilization, sediment control, etc., and assess them in a coordinated basin development scheme, perhaps certain of these, naked under the light of mathematical analysis, might be found unworthy of retention and deserving of sacrifice, as has occurred in the past.

The foregoing considerations present some limitations on feasible actions in applying wide-spread watershed management measures. However, coupled

with facts concerning the resources and their use in the Eel River Basin, certain conclusions can be made from a watershed management point-of-view.

It will be evident in reviewing the ensuing conclusions and watershed management needs that man's detrimental influences on the resources of the Eel River Basin have occurred primarily from three basic factors: (1) ignorance of some of the fundamental relationships between soil, vegetation and water; (2) conflicting interests in the development of a specific individual resource, or a lack of incentive for a "multiple-use" outlook; and (3) a general lack of recognition of the worth of soil and water resources, the effect of use on future needs, and an inability to assess their value in competition with the more conventional products of the land.

The Eel River watershed is an area of somewhat unique properties, problems, and values. Its soils, climate, vegetation, and geology are each individually of note, and have unusual facets which merit attention. Although land use in the Eel River Basin has not been inordinately intense in character, moderate impairment to the basic soil resource has occurred historically from grazing, and more recently from logging and roadbuilding. These problems are not solely characteristic of the Eel River Basin, but exist in a number of watersheds within the State.

The occurrence of redwood groves of international acclaim in the Eel River Basin has attracted world-wide attention to California. Because of the unusual values found in this unique resource, especial care must be exercised to preserve, in as reasonable a manner as feasible, this asset.

Runoff in the Eel River Basin transports sediment at a rate which could conceivably have adverse effects upon proposed water development schemes. This sediment is derived from both natural and man-aggravated sources, the proportion of each being largely unknown.

A great deal of information necessary for the intelligent management of lands within the Eel River watershed is not available. Reliable information

is needed on the occurrence and mechanics of landslides, on sediment production and transport, on land use effects on water yields, and on resident soils in unsurveyed areas.

There is some question that the present system of resource administration and regulation fully recognizes the role of land users in causing erosion and the effect of the resulting sediment. In this respect, the present system appears to be inadequate.

Watershed management needs, as requested in the authorizing Senate Concurrent Resolution, are implicit in the specific items that follow. The reader should be cautioned that these comments are by no means exhaustive, and that they represent somewhat idealistic conditions of human behavior and control.

1. The basic need in watershed management in the Eel River Basin is for an interested public to be well informed as to the nature and occurrence of erosion and sedimentation. The public should also be aware of the ways to achieve good watershed management and the beneficial effect of such management on the economy. There should be mutual appreciation of goals between both individual or private interests and agencies representing the broad public concern. Toward this end, public educational activities in the fields of resources conservation and use should be supported and encouraged by all interests.

2. Because of the lack of information necessary for intelligent watershed management, research in the mechanism and characteristics of landslides, sediment production and transport, hydrologic variations under different conditions of use, and water yields of small basins will be of value, and should be supported. Similarly, the Cooperative Soil-Vegetation Surveys should be extended into Trinity County and into the National Forest Lands in Mendocino County.

3. Periodic inspections of the advance of phreatophytic vegetation, especially salt cedar, in the environs of the Eel River should be

made and analyzed. Although this riparian vegetation is presently of little importance in the Eel River watershed, it is known to exist in some of the adjacent basins.

4. As a great deal of the man-aggravated soil movement is attributable to the inappropriate location, construction, and maintenance of secondary and tertiary roadways, more complete and enlightened engineering and geologic services in these matters would be of value.

5. As the population of urban communities in the Eel River Basin increases, surface sources of water from smaller streams will undoubtedly be developed for domestic consumption. Developing communities should consider the possibility of acquiring tributary lands for the establishment of municipal watersheds.

6. The increasing interest in and consideration of the importance of the role of watershed management in our society has not yet occasioned a clear definition of the responsibility for downstream effects upon the upstream user. Specifically, a definite need exists for some impetus for the timber harvesters (and other land users as well) to recognize and account for these consequences.

7. Because of the unusual problems of sediment production (both natural and accelerated) in the Eel River Basin, a detailed study of the possible causes, effects, and the solutions to these problems should be made before proceeding further with the development of the waters in the Upper Eel River or the Middle Fork Eel River for export.

8. There appears to be little need, and limited potential, for the improvement of water yield through the management of snow or the judicious removal of vegetation in the Eel River Basin. Some benefits in the reduction of sediment production can result from the maintenance and rehabilitation of watershed lands.

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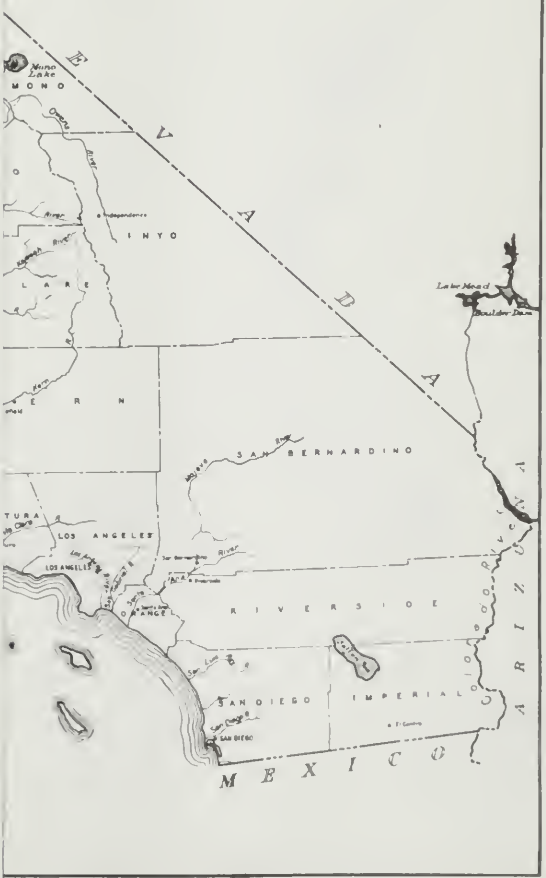
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

NORTH COASTAL AREA INVESTIGATION
1963

LOCATION OF EEL RIVER WATERSHED

SCALE OF MILES
30 0 30 60 90



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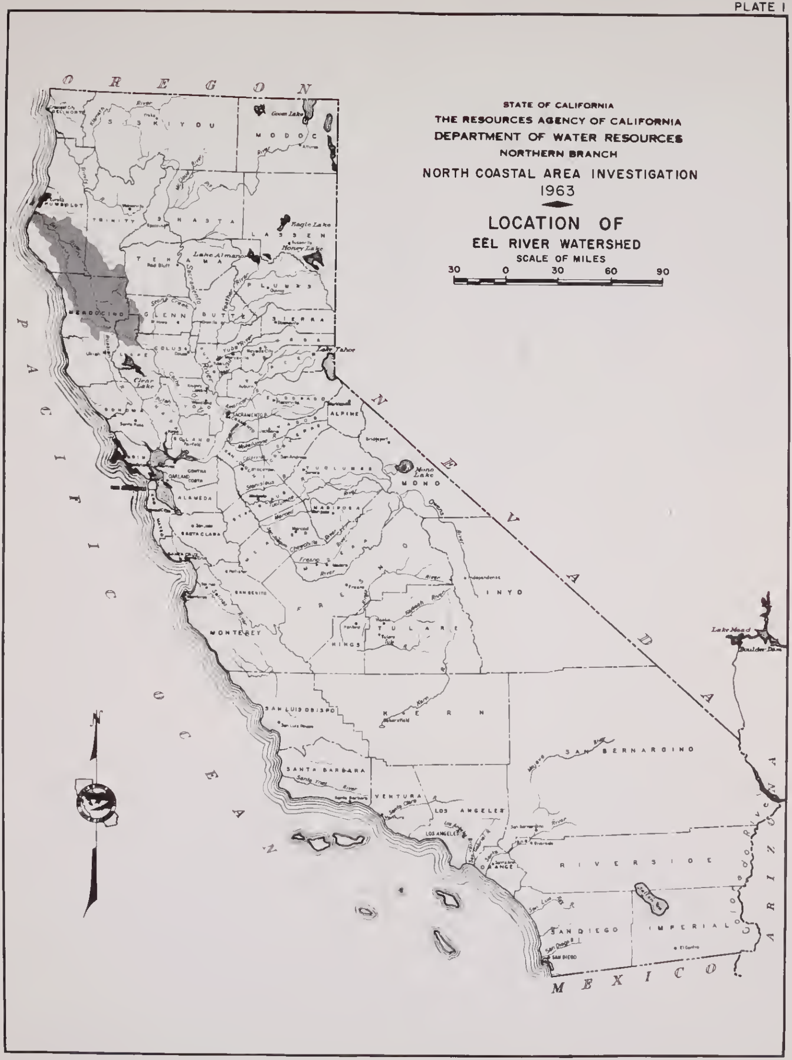
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THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
NORTH COASTAL AREA INVESTIGATION
1963
LOCATION OF
EEL RIVER WATERSHED
SCALE OF MILES
30 0 30 60 90
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
COLUSA
LAKE
SONOMA
YOLO
ALPINE
MONO
ALAMEDA
MARIPOSA
INYO
FRESNO
MONTEREY
SAN BENITO
TULARE
KINGS
KERN
SAN LUIS OBISPO
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
RIVERSIDE
SAN DIEGO
IMPERIAL
Goose Lake
Eagle Lake
Honey Lake
Lake Almanor
Lake Tahoe
Clear Lake
Mono Lake
Lake Mead
Boulder Dam
SACRAMENTO
OAKLAND
LOS ANGELES
SAN DIEGO


Newville
GLENN
Elk Creek
Alder Sprs
Brushy Mtn
RIDGE
LAKE
COLUSA
Stonyford
Middle
Eel R
Potter Valley
Redwood Valley
Willits
MENDOCINO
Calpella
Ukiah
Upper Lake
20
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
NORTH COASTAL AREA INVESTIGATION
1963
CLIMATIC CLASSIFICATIONS
EEL RIVER WATERSHED
SCALE OF MILES
4 0 4 8 12


STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
NORTH COASTAL AREA INVESTIGATION
1963
DISTRIBUTION OF PRECIPITATION
EEL RIVER WATERSHED
SCALE OF MILES
4 0 4 8 12
LEGEND
40 MEAN SEASONAL PRECIPITATION IN INCHES
EEL RIVER WATERSHED BOUNDARY
NOTE
MEAN SEASONAL PRECIPITATION BASED ON PERIOD 1905-06 TO 1954-55
PACIFIC OCEAN
HUMBOLDT
TRINITY
GLENN
LAKE
MENDOCINO
EEL RIVER
YOLLA BOLLY

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

NORTH COASTAL AREA INVESTIGATION
1963

GENERAL GEOLOGY
EEL RIVER WATERSHED

SCALE OF MILES
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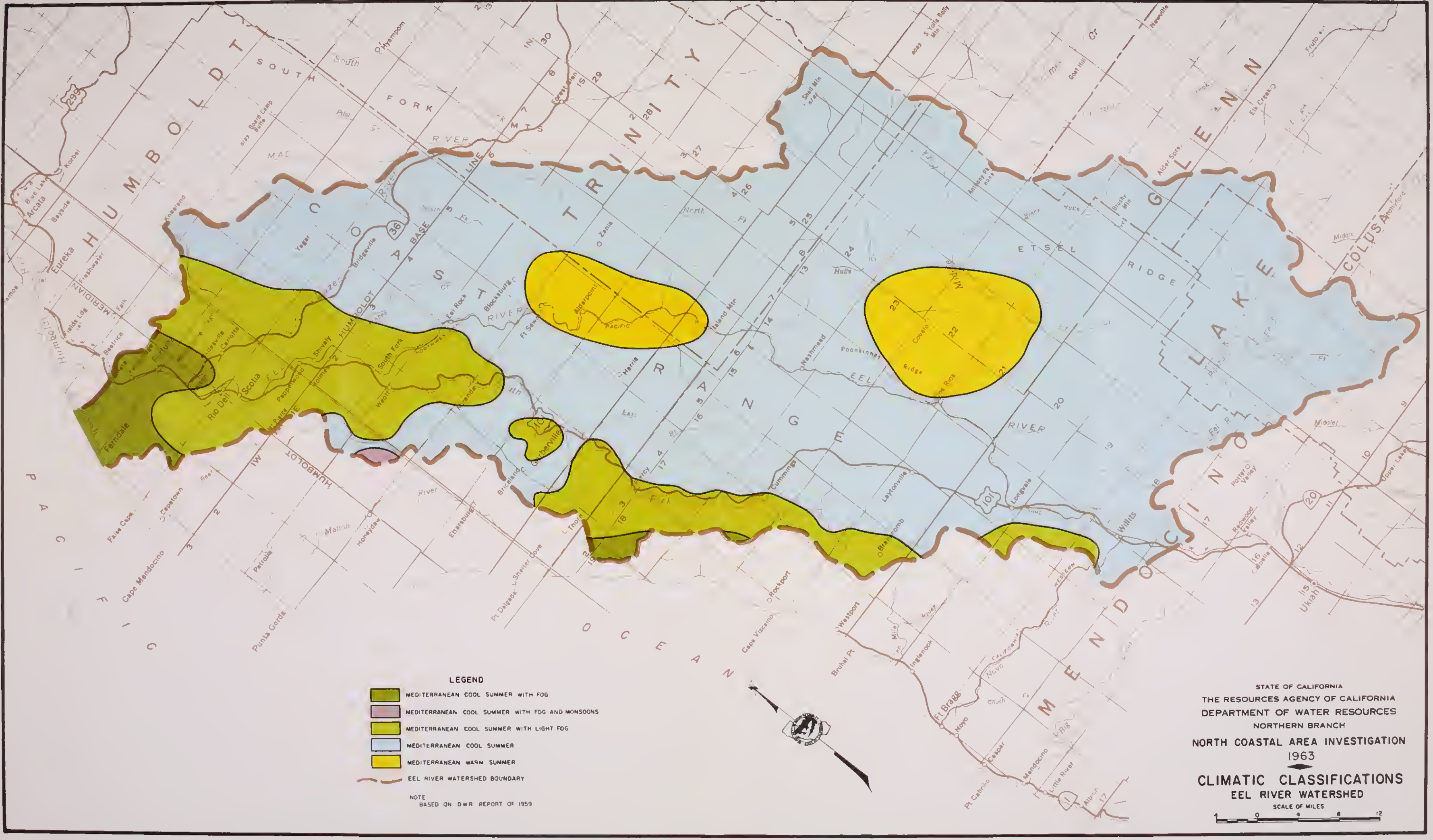
PLATE 3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MEDITERRANEAN COOL SUMMER WITH FOG AND MONSOONS
MEDITERRANEAN COOL SUMMER WITH LIGHT FOG
MEDITERRANEAN COOL SUMMER
MEDITERRANEAN WARM SUMMER
EEL RIVER WATERSHED BOUNDARY
NOTE
BASED ON DWR REPORT OF 1959
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
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1963
CLIMATIC CLASSIFICATIONS
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SCALE OF MILES
4 0 4 8 12
HUMBOLDT
TRINITY
MENDOCINO
GLENN
LAKE
COLUSA
PACIFIC OCEAN
Eureka
Arcata
Ferndale
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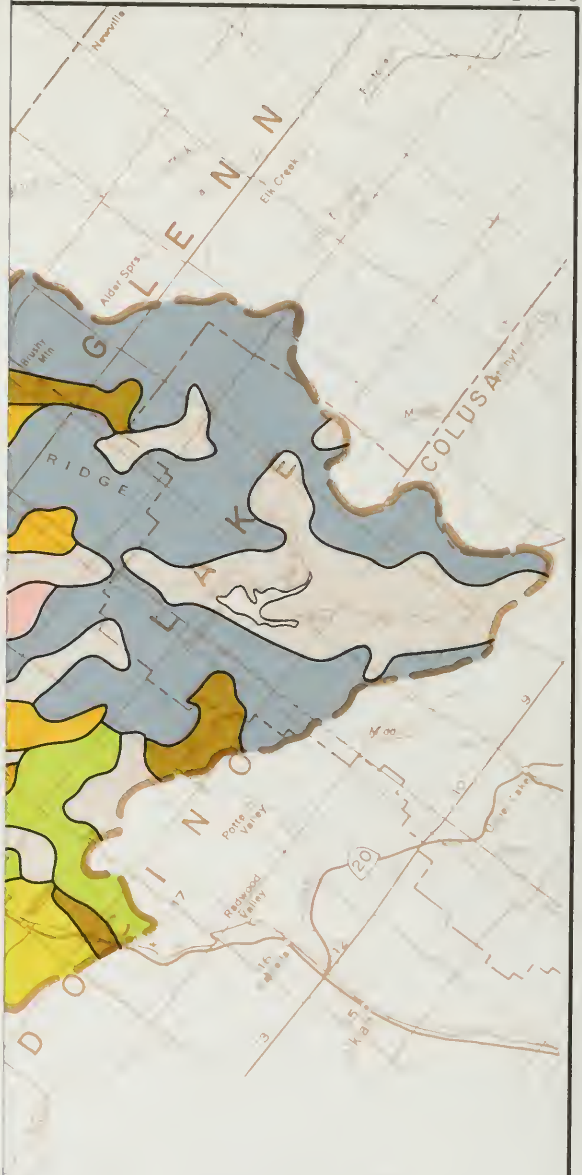
Covelo
Laytonville
Willits
Ukiah
Ft Bragg
EEL RIVER



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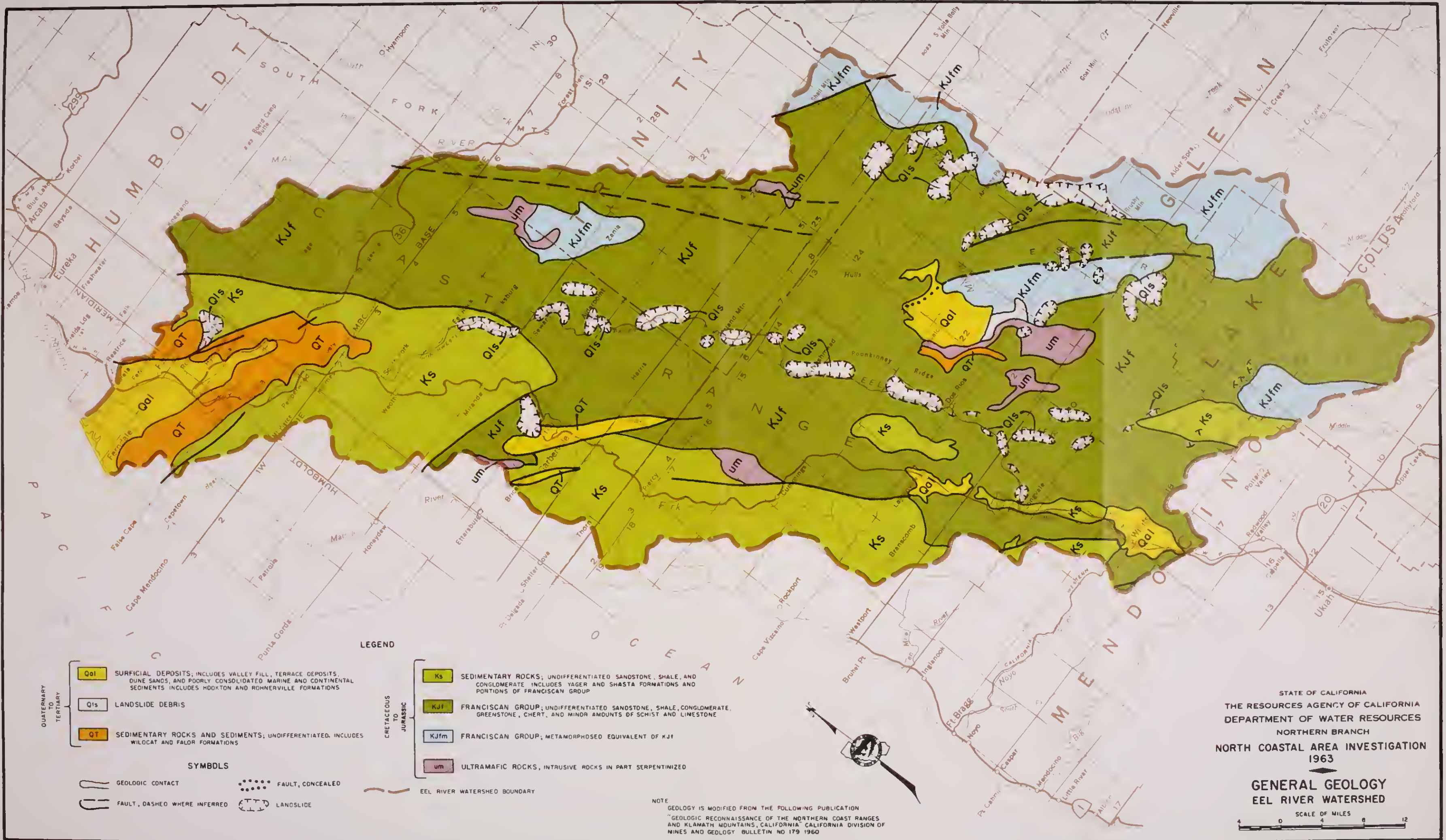
NORTHERN BRANCH

NORTH COASTAL AREA INVESTIGATION
1963

DISTRIBUTION OF VEGETATION
EEL RIVER WATERSHED

SCALE OF MILES
4 0 4 8 12

PLATE 4



LEGEND
QUATERNARY TO TERTIARY
Qal SURFICIAL DEPOSITS; INCLUDES VALLEY FILL, TERRACE DEPOSITS, DUNE SANDS, AND POORLY CONSOLIDATED MARINE AND CONTINENTAL SEDIMENTS INCLUDES HOOKTON AND ROHNERVILLE FORMATIONS
Qls LANDSLIDE DEBRIS
QT SEDIMENTARY ROCKS AND SEDIMENTS; UNDIFFERENTIATED. INCLUDES WILDCAT AND FALOR FORMATIONS
CRETACEOUS TO JURASSIC
Ks SEDIMENTARY ROCKS; UNDIFFERENTIATED SANDSTONE, SHALE, AND CONGLOMERATE. INCLUDES YAGER AND SHASTA FORMATIONS AND PORTIONS OF FRANCISCAN GROUP
KJf FRANCISCAN GROUP; UNDIFFERENTIATED SANDSTONE, SHALE, CONGLOMERATE, GREENSTONE, CHERT, AND MINOR AMOUNTS OF SCHIST AND LIMESTONE
KJfm FRANCISCAN GROUP; METAMORPHOSED EQUIVALENT OF KJf
um ULTRAMAFIC ROCKS, INTRUSIVE ROCKS IN PART SERPENTINIZED
SYMBOLS
GEOLOGIC CONTACT
FAULT, DASHED WHERE INFERRED
FAULT, CONCEALED
LANDSLIDE
EEL RIVER WATERSHED BOUNDARY
NOTE
GEOLOGY IS MODIFIED FROM THE FOLLOWING PUBLICATION
"GEOLOGIC RECONNAISSANCE OF THE NORTHERN COAST RANGES AND KLAMATH MOUNTAINS, CALIFORNIA" CALIFORNIA DIVISION OF MINES AND GEOLOGY BULLETIN NO 179 1960
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DEPARTMENT OF WATER RESOURCES
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NORTH COASTAL AREA INVESTIGATION
1963
GENERAL GEOLOGY
EEL RIVER WATERSHED
SCALE OF MILES
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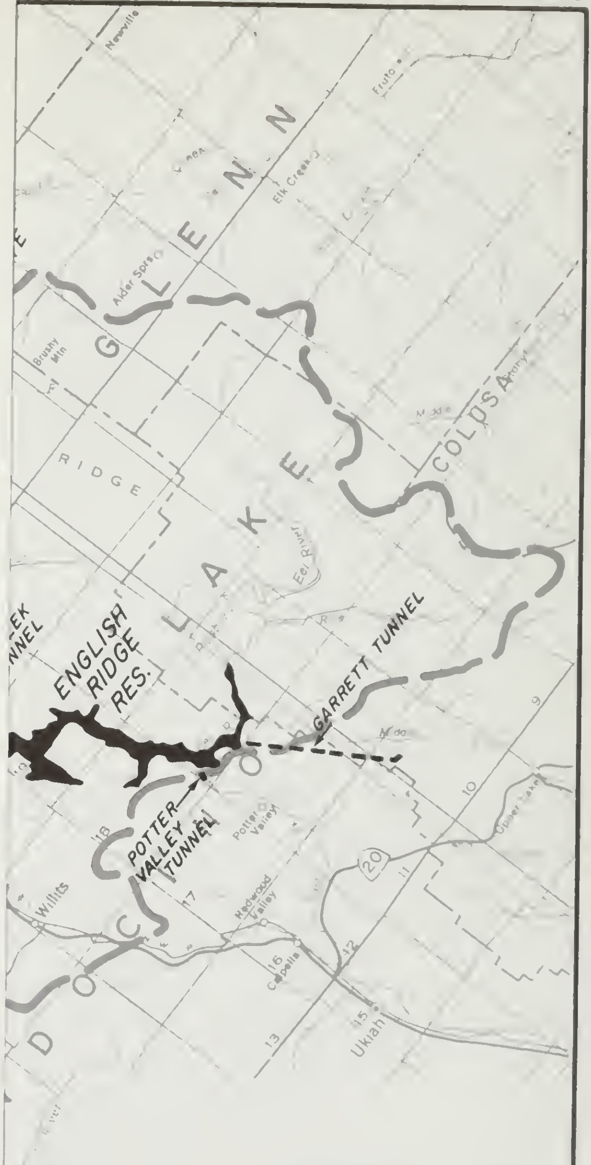
HUMBOLDT
TRINITY
GLENN
COLUSA
LAKE
MENDOCINO
PACIFIC OCEAN
Eureka
Arcata
Ferndale
Cape Mendocino
Ft. Bragg
Ukiah
Willits
Covelo
Garberville
Westport



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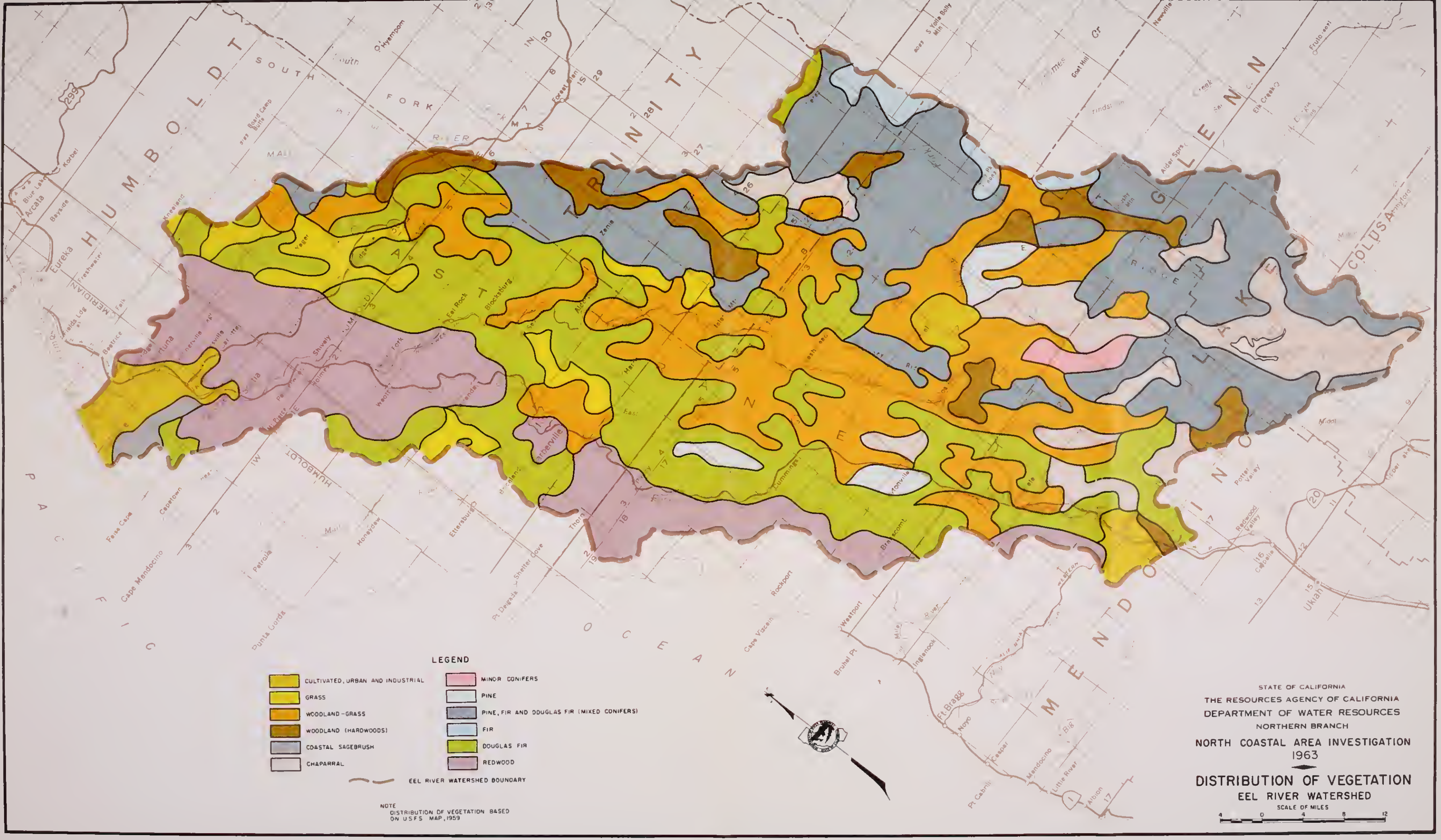
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH

NORTH COASTAL AREA INVESTIGATION
1963

POSSIBLE WATER PROJECTS
EEL RIVER WATERSHED

SCALE OF MILES
4 0 4 8 12

PLATE 5


LEGEND
CULTIVATED, URBAN AND INDUSTRIAL
GRASS
WOODLAND-GRASS
WOODLAND (HARDWOODS)
COASTAL SAGEBRUSH
CHAPARRAL
MINOR CONIFERS
PINE
PINE, FIR AND DOUGLAS FIR (MIXED CONIFERS)
FIR
DOUGLAS FIR
REDWOOD
EEL RIVER WATERSHED BOUNDARY
NOTE
DISTRIBUTION OF VEGETATION BASED ON U.S.F.S. MAP, 1959
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THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
NORTHERN BRANCH
NORTH COASTAL AREA INVESTIGATION
1963
DISTRIBUTION OF VEGETATION
EEL RIVER WATERSHED
SCALE OF MILES
4 0 4 8 12
HUMBOLDT
TRINITY
GLENN
COLUSA
LAKE
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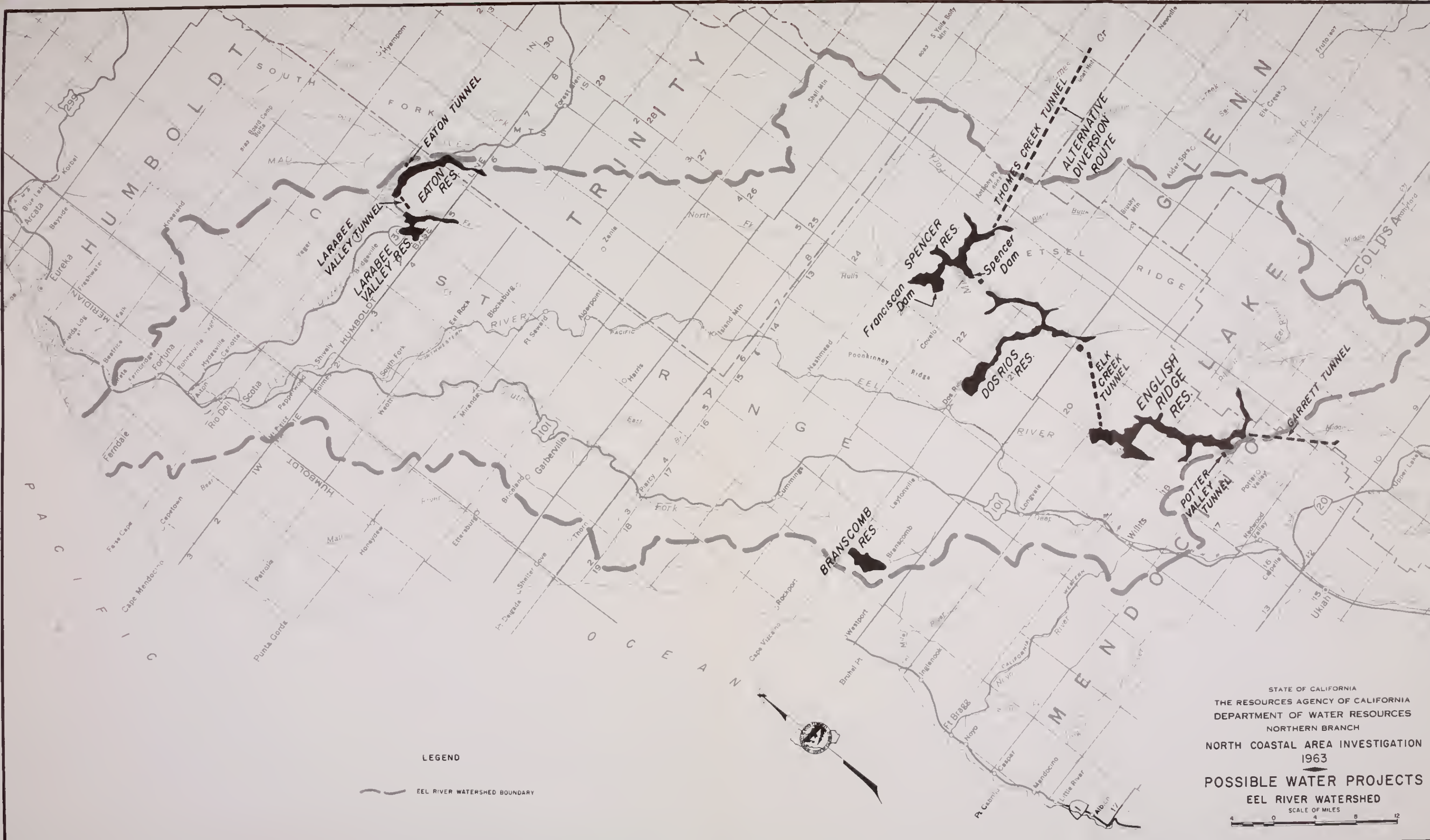
Eureka
Arcata
Fortuna
Garberville
Ukiah
Ft. Bragg
Westport
Willits


EATON TUNNEL
EATON RES.
LARABEE VALLEY TUNNEL
LARABEE VALLEY RES.
SPENCER RES.
Spencer Dam
Franciscan Dam
THOMES CREEK TUNNEL
ALTERNATIVE DIVERSION ROUTE
DOS RIOS "2" RES.
ELK CREEK TUNNEL
ENGLISH RIDGE RES.
GARRETT TUNNEL
POTTER VALLEY TUNNEL
BRANSCOMB RES.
HUMBOLDT
TRINITY
GLENN
COLUSA
LAKE
MENDOCINO
SOUTH FORK MTS
ETSEL RIDGE
PACIFIC OCEAN
EEL RIVER
Eureka
Arcata
Fortuna
Ferndale
Scotia
Rio Dell
Garberville
Laytonville
Willits
Ukiah
Covelo
Fort Bragg
LEGEND
EEL RIVER WATERSHED BOUNDARY
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
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NORTHERN BRANCH
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1963
POSSIBLE WATER PROJECTS
EEL RIVER WATERSHED
SCALE OF MILES
4 0 4 8 12

PR